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**EVALUATION OF THE CONSTRUCTION EQUIPMENT  
REPLACEMENT POLICIES OF CONSTRUCTION  
CONTRACTORS IN THE EASTERN PROVINCE  
OF SAUDI ARABIA**

BY

**Ahmed Ali Al-Ghamdi**

A Thesis Presented to the  
DEANSHIP OF GRADUATE STUDIES

**KING FAHD UNIVERSITY OF PETROLEUM & MINERALS**

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the  
Requirements for the Degree of

**MASTER OF SCIENCE**

In

**CONSTRUCTION ENGINEERING & MANAGEMENT**

**NOVEMBER 2001**

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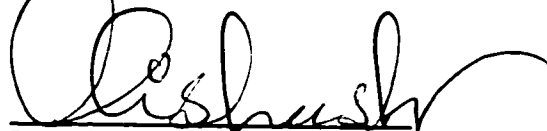
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*This thesis, written by*

**AHMED ALI AL-GHAMDI**

under the direction of his thesis advisor and approved by his thesis committee, has been presented and accepted by the Dena of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING & MANAGEMENT**

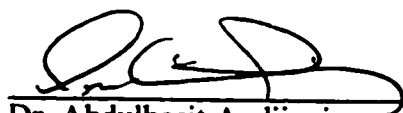
**Thesis Committee:**



Dr. Ali A. Shash



Dr. Sadi Assaf



Dr. Abdulbasit Andijani



Dr. Mohammed Al-Khalil



Dr. Soliman Almohawis  
Department Chairman



Dr. Osama A. Jannadi  
Dean of Graduate Studies



Date: -----

## **DEDICATION**

**Dedicated to my wife for here continuous sacrifices and support throughout my master program.**

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## **THESIS ABSTRACT**

**NAME:** AHMED ALI AL-GHAMDI

**TITLE:** EVALUATION OF THE CONSTRUCTION EQUIPMENT REPLACEMENT POLICIES OF CONSTRUCTION CONTRACTORS IN THE EASTERN PROVINCE OF SAUDI ARABIA

**MAJOR:** CONSTRUCTION ENGINEERING AND MANAGEMENT

**DATE:** NOVEMBER 2001

The objective of this thesis is to study the equipment replacement methods and practices of major contractors in the Eastern Province of Saudi Arabia, to present the most popular practice of the contractors.

The needed data were collected via a structured questionnaire from 21 contractors out of 70 contractors in the population. The contractors were divided into three grades based on their annual work volumes. The collected data were analyzed using the SAS software which produces statistics, frequency, and cross tabulation charts.

The elements of the equipment replacement policies were cross-tabulated against the grades of the contractors for finding possible significant differences in the contractor's practices. The equipment replacement methods along with the factors that are considered during the financial evaluation of the equipment replacement proposals were identified and studied in order to find the best replacement practice. Finally, the findings of this study were compared with findings of similar studies conducted in USA for finding significant commonalities and differences in equipment replacement practices.

Although only one-third of the contractors have written equipment replacement policy, all the contractors practice almost similar and uniform procedures for selecting, acquiring, operation and maintenance, record keeping, and replacement analysis. It was interesting to notice that contractors in Saudi Arabia follow replacement procedures that are almost similar to those procedures followed by contractors in USA.

**MASTER OF SCIENCE DEGREE**  
**KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS**  
Dhahran, Saudi Arabia  
November 2001



## ملخص البحث

الاسم : أحمد علي الغامدي

مسمى البحث : تقييم طرق احلال المعدات الانشائية لمقاولي الانشاءات بالمنطقة الشرقية في المملكة العربية السعودية

التخصص : هندسة وإدارة التشييد

التاريخ : نوفمبر 2001 م

الغرض من هذا البحث هو دراسة طرق احلال المعدات الانشائية التي يتبعها كبار المقاولين بالمنطقة الشرقية من المملكة العربية السعودية وذلك للوصول إلى أمثل الطرق المتبعة في هذا المجال .

المعلومات اللازمة لهذه الدراسة جمعت بواسطة مسح ميداني عن طريق استبيان وزع على سبعين ( 70 ) مقاولاً واستجاب للاستبيان واحد وعشرون ( 21 ) مقاولاً. وتم توزيع هؤلاء المقاولين إلى ثلاث مجموعات بناءً على أحجام أعمالهم التجارية السنوية , كما تم تحليل هذه المعلومات باستخدام برنامج " SAS " الاحصائي. وقد تم ربط مقومات وعوامل احلال المعدات مع البيانات والجداول التي استخلصت من البرنامج الاحصائي " SAS " وذلك لمعرفة الفروقات بين الطرق المتبعة من قبل المقاولين.

كما تم تحديد طرق احلال المعدات والعوامل التي يتم دراستها خلال عملية تقييم عروض احلال المعدات الانشائية. كذلك تم مقارنة نتيجة الاستبيان مع بعض الاستبيانات التي سبق أن أجريت في الولايات المتحدة الامريكية للتعرف على أوجه الشبه والاختلاف بين الطرق المتبعة في كلتي الدولتين والاستفادة من تجارب المقاولين الامريكيين في هذا المجال.

وبالرغم من أن ثلث المقاولين فقط لديهم طرق موثقة لتغيير المعدات , فإن كل المقاولين يمارسون طرق مماثلة وموحدة في مجالات الاختيار, الطلب, التشغيل والصيانة, حفظ التقارير, وتحليل عروض التغيير. ولقد لوحظ أن المقاولين في المملكة العربية السعودية غالباً ما يتبعون طرقاً مماثلة لتلك المتبعة في الولايات المتحدة الامريكية.

درجة الماجستير في العلوم

جامعة الملك فهد للبترول والمعادن  
الظهران — المملكة العربية السعودية  
نوفمبر 2001 م

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# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 GENERAL**

The equipment required to conduct construction work is an extremely vital factor in modern competitive operations, particularly for construction companies. Production planning for a project often focuses on the operational output. Furthermore, the financial planning for an entire construction business often stems from the investment in equipment, since the total of this element constitutes the largest long-term capital investment in the business.

Construction equipment constitutes a major investment for most construction firms. Surveys in the past have shown that almost 50% of the construction firms of all sizes own the equipment they use (Tavakoli, 1989). It is therefore essential that the users be aware of the technology, applications, and management of construction equipment.

A uniform equipment policy has to be drawn to establish the rules for prudent management of equipment. The equipment policy has a great impact on the profitability of the firm by governing the ways to utilize the equipment to its full potential and hence increase the profits accrued by them to their owners. The policy provides guidance for the management, operation, and maintenance divisions of the firm to manage and control the equipment in all areas related to the equipment. The various steps involved in the management of construction equipment during the lifetime of the equipment are as follows:

1. Decision to acquire a piece of equipment
2. Selection of the right equipment

3. Method of acquiring the equipment
4. Utilization of the equipment
5. Replacement and disposal of the equipment

All the above processes are to be done in a proper manner based on the requirements, operating policies, and principles of the organization. Control of these processes requires a comprehensive equipment management policy. An equipment policy should contain the rules to be followed when dealing with the equipment. These rules must ensure that the interests of the organization are protected.

The decision to acquire equipment is taken normally after a detailed study of its need. The new equipment might be a replacement for a retired one or a support to the firm's projects. This is followed by determining the right type and size of equipment. Various issues need to be addressed at this stage. These include what type of equipment is to be acquired and its required capacity. If any particular brand or manufacturer is preferred, then this should be stated. Also, the cost of acquiring and maintaining it should be calculated. If there is no policy to guide the process, there is a high probability that an inappropriate selection will be made. The next step in the process is acquiring the desired equipment. The appropriate equipment is located in the market. From a calculation of the economics of the equipment and a review of the economic standing of the organization, a decision is reached whether to buy, rent, or lease the equipment. There are many options to be considered when buying the equipment. The firm can purchase it outright or finance it through an independent organization or the dealer. Bad decisions at this stage can result in a bad deal, which can cost the organization, not only at the time of acquiring the equipment but throughout its life. The next step is utilization of the equipment, where the user has to be familiar with the operation and maintenance of the equipment. All the costs of

operation and maintenance have to be recorded. The equipment has to be kept in top condition so as to remain productive. To check the productivity of the equipment, productivity records have to be kept, so operation and maintenance people need a policy to perform all the required tasks in a way that maximizes the firm's profits and ensures the safety of the personnel.

The last stage is the replacement and disposal stage. This takes place when the equipment has reached a point where its operation is no longer profitable. This may be due to deterioration or obsolescence of the equipment or availability of new models that have better quality, bigger capacity, or operate at lower cost. At this stage the decision will be to dispose of the existing equipment and acquire a replacement.

To manage the last stage, some firms tend to have a stand-alone equipment replacement policy rather than having it as part of an overall equipment replacement policy. This is due to the importance of this stage and the effects of the replacement decision on the firm's profit and project execution and schedule.

The equipment replacement policy is the area of study of this research. The existing equipment replacement policies of construction contractors in the Eastern Province of Saudi Arabia will be assessed and evaluated.

## **1.2 PROBLEM STATEMENT**

Construction equipment is a major investment for most construction firms in Saudi Arabia. It is therefore essential for them to be careful in making decisions regarding these major assets. The decision should be taken after thorough analysis and study of all the various aspects of the problem. When to replace construction equipment is a problem that construction firms regularly



face. The typical answer for this question is to replace the equipment when it reaches a point where it is no longer profitable to operate.

Advanced technologies often make equipment replacement an attractive option. New models promise lower cost, better quality, greater capacity, and ease of operation. However, replacement decisions may have serious effects on the firm's liquidity, operational flexibility, and profits.

If the decision is taken to replace the equipment earlier than its expected time, the firm will lose money due to the early acquisition of equipment. If the purchase had been delayed, the money could have been invested elsewhere. Additionally, the salvage value might not be as planned. If the replacement decision is delayed, then operating and maintenance costs might increase dramatically, additional overhead might be required, and the salvage value might be less than desired. In addition, if the equipment was to fail during this period, the firm would face heavy financial losses, schedules would be delayed, and additional funds would be required to either quickly repair the equipment or purchase a new one.

It is, therefore, evident that an equipment replacement policy is necessary in order for construction personnel to study and evaluate replacement needs and to make the right replacement decision at the right time.

The literature searches showed that there have been no previous studies conducted to survey and analyze the equipment replacement policies of construction contractors in Saudi Arabia. This justifies the need for this research.

The study aims to provide contractors, dealers and other interested parties, public, private and academic, with the current status of the equipment replacement policies of construction contractors in the Eastern Province of Saudi Arabia.

## **1.2.1 RESEARCH QUESTIONS**

The following six research questions will drive this research study.

1. Do construction contractors have a written equipment management policy? If yes, then what are the elements of such policies?
2. Do construction contractors have a written equipment replacement policy? If yes, then what are the elements of such policy?
3. Do construction contractors have a written procedure governing the economic life of their equipment? If yes, then what are the elements of the procedure?
4. What are the financial methods used to evaluate equipment replacement proposals
5. What are the factors controlling the equipment replacement decision?
6. What are the management structures and how is management of equipment undertaken in large, medium, and small organizations?

## **1.3 OBJECTIVES OF THE STUDY**

There are three main objectives to this study:

1. Investigate and identify construction equipment replacement methods.
2. Study the factors that are considered in the replacement process.
3. Evaluate the equipment replacement policies of construction contractors in the Eastern Province of Saudi Arabia.

## **1.4 SIGNIFICANCE OF THE STUDY**

The study has the following advantages:

1. It will shed light on how much attention is given to the equipment, when and why owners tend to replace it, the replacement methods used, and the issues considered.
2. It will contribute to the literature since currently there are no articles that look at the methodologies used by Saudi Arabian construction contractors to evaluate equipment replacement proposals.
3. The evaluation document will be a good reference point for future research.
4. The conclusions drawn from this study will help contractors improve or create an equipment replacement policy.

## **1.5 SCOPE AND LIMITATIONS**

Evaluation of the existing replacement policies will include all the construction equipment owned by construction contractors. Due to a limitation in time and money, the study will be limited to construction contractors in the Eastern Province of Saudi Arabia.

## **CHAPTER 2**

### **LITERATURE REVIEW**

Before the industrial revolution, man relied upon tools to do his work. After the industrial revolution tools and animals were replaced by machines that could work faster and consume fewer resources. In short, the machines were more productive. This change was felt in every field; the construction industry was no exception. Machines were made that could do all sorts of work related to construction, ranging from digging and trenching to filling and tamping. As technology progressed, a profound effect on pieces of construction equipment took place. They became faster, more powerful, more productive, and lasted longer. Now there are many types of construction machines on the market, and they are used for various jobs in the field. The most popular pieces of equipment are those that are used in excavating and moving earth (such as shovels, hoes, draglines, scrapers, trucks, and belt conveyor systems), lifting equipment (such as cranes, mechanical lifts), and concrete equipment (such as mixing drums, trucks, concrete pumps etc). There is also other specialized equipment used for tunneling, driving piles, and pumping water and compressed air.

The construction industry is separated into two distinct groups – civil engineering and building engineering. Civil engineering is concerned with the establishment of the nation's infrastructure of roads, bridges, dams, sewers, power supplies, etc., while building engineering concentrates on housing, factories and offices. Civil engineering utilizes heavy equipment like earthmoving equipment, while building engineering mainly utilizes cranes and other lifting devices.

## **2.1 EQUIPMENT MANAGEMENT POLICY**

Equipment management is crucial to the profitable utilization of equipment. Contractors who have large equipment fleets should have a strategic plan for successful management of these fleets. Planning fleet strategy with decision-makers from throughout the company keeps equipment ownership on track with the firm's goals [Stewart, 1997]. Strategic management requires the cooperation between the different management teams of estimating, project management, accounting and the firm owners. The written equipment policy goes a long way to ensure this cooperation between different divisions of management. The equipment policy has a great impact on the profitability of the firm by governing the ways to utilize equipment to its full potential and hence increase the profits accrued by them. The policy provides decision-making guidance regarding equipment to the management, operation, and maintenance divisions of the firm. The following sections present the issues relevant to this topic.

### **2.1.1 Equipment Selection**

Equipment selection is a critical factor when trying to complete a project within budget and on schedule. Without proper working equipment, productivity decreases, delays increase, possible injuries occur and unnecessary costs are incurred. It is important to all the parties on a construction site that a project begins with appropriate selection of the equipment needed to perform the work [Amirkhanian and Baker, 1992]. Proper selection of equipment contributes to project efficiency and to increased profits.

Selection of the correct plant for the job ideally forms part of the construction planning process, and equipment should be chosen for a particular task only after analysis of many interrelated factors.

The important considerations for selecting equipment include the following [Harris, 1981]:

1. The function to be carried out,
2. The capacity of the machine,
3. The method of operation,
4. The limitations of the method,
5. The cost of the method, and
6. The cost comparison with other methods.

Lowest overall cost is the prime consideration in buying a piece of construction equipment.

There are four factors to be considered [Puerifouy and Ledbetter, 1985]:

1. **Machine productivity:** In construction operations, the production requirement is a known quantity. The best size of equipment is chosen to deliver that production at the lowest cost. It is also important to distinguish between primary and secondary usage of the equipment. Operating conditions have substantial effect on equipment productivity.
2. **Product features and attachments:** Construction equipment is available with a wide variety of features and attachments that offer greater productivity, broader applications, versatility, increased operating safety and improved operator convenience. These features should be evaluated with complete objectivity.
3. **Dealer support:** From the moment of purchase to the final resale, the equipment dealer plays an important part in determining the efficiency of the equipment.

4. **Price:** The total cost of owning and operating a machine and not the price alone should be the basis for decision making when purchasing equipment.

### **2.1.2 Equipment Acquisition**

Contractors and other users of construction equipment are concerned with a decision as to whether to purchase, or rent, or lease equipment. Under certain conditions, it is financially advantageous to purchase, whereas under other conditions it is more economical and satisfactory to rent. Following are three methods by which a contractor may secure the use of construction equipment [Douglas, 1975]:

1. **Purchase**
2. **Lease**
3. **Rent**

The method selected should be the one that will provide the use of the equipment at the lowest total cost, consistent with the use that the contractor will make of the equipment.

The decision to acquire an asset should be made for both technical and economic reasons. The profitability of the proposal should be evaluated by calculating the expected rate of return and comparing it with the cost of capital. The decision as to how to acquire the asset can then be considered as a financial decision. The major factors that influence the decision as to which is the most advantageous are as follows [Harris and McCaffer, 1991]:

1. **Tax savings from the purchase of construction plant**
2. **The profit flows of the acquiring company**

3. The acquiring company's cash flows, which determine what money is available for plant acquisition
4. The acquiring company's gearing ratio (borrowed capital/equity capital), which influences the amount of further borrowing possible.

### **Purchase**

Outright purchase is simply payment of purchase price by the acquiring company to the supplier. This involves the acquiring company in a large cash payment very early, before the equipment has acquired any revenue. However, outright purchase provides acquiring company with capital allowances written down of the purchase price of the equipment (Harris and McCaffer, 1991). If cash is available from within the company's own resources or even from an overdraft, this form of acquisition is the cheapest. Outright purchase places the title of the equipment immediately with the acquiring company. This means that the equipment becomes an asset over which the company has full control, which it can use to negotiate finance, which it can use anywhere, and which it can dispose off to produce cash from its resale value.

Other methods of purchase include credit sale and hire purchase. A credit sale is a sale in which the acquiring company takes the ownership or title of the equipment immediately but the purchase price is paid in installments. These installments include the purchase price plus any financing charges of the supplier.

Hire purchase is a contract where by the acquiring company pays a regular hire charge and, at some predetermined point after payment of a proportion of the agreed hire charges, the acquiring company buys the equipment for a nominal sum. This facility to purchase distinguished the hire



**purchase contract from leasing, which does not permit the acquiring company to purchase the leased equipment.**

**Both hiring purchase and credit sales require cash deposits, but these deposits are much less than the whole purchase price and therefore in cash considerations these form of acquisitions are less demanding than outright purchase. However, the interest charges included in the hire purchase contracts are likely to be greater than those the acquiring company would pay on an overdraft.**

### **Advantages of Purchasing**

**Direct ownership of equipment has the following advantages (Douglas, 1975):**

- 1. It allows the owner to utilize depreciation and interest on the equipment loans as tax deductible business expenses.**
- 2. It improves the psychology of maintenance and pride of operation through direct ownership.**
- 3. It gives the owner complete freedom to use his equipment as he wishes and to dispose of it whenever and wherever he finds advantage.**
- 4. It assures the owner of any investment credit, which may be acquired, with the purchase of the machine.**
- 5. The owner benefits directly from wise disposal and salvage value.**

**Buying equipment has the following advantages (Anon, 1987):**

- 1. It builds assets on the books of the owner.**
- 2. Equipment is always available when needed.**
- 3. Equipment can be bought to fit needs.**
- 4. Gives pride and privilege of ownership.**

## **Leasing**

The difference between leasing and purchasing is that the ownership of the equipment remains the property of the leasing company (the lessor) and the acquiring company (the lessee) never becomes the owner. The acquiring company (the lessee) only acquires the use of the equipment in return for payments or rentals. There are two categories of lease; the finance lease and the operating lease. The finance lease is normally arranged through leasing companies who have no particular interest in the equipment and offer no technical support, but merely arrange the lease. The lessee pays the lessor payments or rentals for the use of the equipment acquired. The equipment is usually supplied by a third party, the equipment manufacturer or dealer from whom the equipment is bought by the leasing company. The operating lease is normally arranged with manufacturer or suppliers who offer such a service as part of marketing their products. Here, the leasing company is the equipment manufacturer.

## **Advantages of Leasing**

The advantages to the user from leasing are (Douglas, 1975):

1. The lease provides another source of credit; it enlarges the credit pool.
2. It releases working capital by providing up too 100% financing for new or used equipment.
3. By its tax advantages, it reduces the contractors tax obligations.
4. It creates a favorable cash flow by paying equipment expenses as they accrue rather than in advance.
5. It improves the contractor's financial ratios.

6. It gives the small contactors more leverage in getting warranties and other obligations of the manufacturer fulfilled.
7. It provides the opportunity for the small contractor to take advantage of the large volume use of the lesser in obtaining lower prices for fuel, tiers, and other supplies.
8. It enables the contractor to utilize the expertise of the engineering staff of the leesor for guidance in the selection of the equipment and its maintenance and management.

Unlike other means of acquiring the use of equipment, leasing can provide befits to the lessee (user) that may not be available through purchasing and financing alternatives. The lessee's consideration of leasing is based on the concept that it's the use of equipment rather than ownership that determines a profit to be made (Caspermeyer, 1981).

The obvious advantage to leasing is acquiring the use of an asset without making a large initial cash outlay (Lerman, 1984). The advantages of leasing compared to a loan arrangement to purchase equipment, according to Lerman are:

1. A lease requires no down payment while a loan usually requires one.
2. A lease requires no restrictions on a company's financial operations, while loans often do.
3. A lease spreads payments over a longer period than loans, and
4. A lease provides protections against the risk of equipment obsolescence, since the lessee can get of the equipment at the end of the lease.

## **Hiring (Renting)**

The difference between hiring (renting) and leasing is that leasing is regarded as a long term hiring. Hiring is the use of equipment by the lessee for short terms such as daily, weekly, or monthly periods. When equipment is hired the lessor provides the required repair and maintenance, whereas in a leasing arrangement the repair and maintenance of the equipment is the lessee's responsibility. The individual renting a piece of equipment would only have to pay for the equipment as it is needed (Anon, 1987).

Some of the advantages of renting are (Anon, 1987):

1. No maintenance cost.
2. Newer equipment.
3. No disposal problems.
4. Cost accounting simplified.
5. Flexibility on job planning.
6. Labor downtime is less.
7. Use for seasonal purposes, e.g. snow seasons.
8. Fixed rate cost (No hidden cost of ownership).
9. Line of credit not tied up as it would be on a purchase.

### **2.1.3 Equipment Maintenance**

Maintenance is the general upkeep of the equipment. Construction equipment like any other equipment will breakdown during its life. This is due to normal wear and tear or to sudden failure of a component part. The primary purpose of providing maintenance is to reduce the incidence of failure. This is done by replacement, repair or servicing in order to achieve an

economical level of utilization during the working life of the machine. The reduction of downtime minimizes costly stoppages on the construction site and the disruptive effect on the labor and schedule of work. The cost of maintenance has to be balanced against the benefits, and at some stage a piece of equipment will require replacement.

Maintenance includes all the labor (both direct and indirect), material, plant, and overhead required to sustain equipment in good, serviceable condition. It includes periodic inspection, lubrication, servicing, repairs and overhauls. A maintenance system should include the following provisions for all degrees of maintenance:

1. Preventive maintenance
2. Repairs
  - Minor or field
  - Major or shop
  - Overhauls

#### **2.1.4 Cost, Time, and Production Records**

All owners of construction equipment must keep cost, time, and production records of their equipment. This is not only necessary from an accounting standpoint but also from a control standpoint. The extent of these records will vary with the type of work, competition, and pressures on the contractor to improve efficiency of the operation.

Cost, time, and production records are kept for several reasons [Douglas, 1975]:

1. For cost control of the job in progress
2. To assess the financial condition of the firm
3. To assess progress on the job

4. To set standards of cost, time, and production
5. To be used as a basis of litigation
6. To establish tax liability
7. To collect data for economic analysis

### **Types of Records**

**Cost Records:** A permanent record of the annual costs of individual machines should be kept in the following categories [Douglas, 1975]:

1. Revenue
2. Fixed costs
  - a. Depreciation
  - b. Interest, insurance, and taxes
  - c. Storage and security
  - d. Fees, licenses, and fines
  - e. Moving
  - f. Overhead
3. Variable costs
  - a. Maintenance
  - b. Field repairs
  - c. Fuel
  - d. Tires or tracks
  - e. Operating labor
  - f. Field supervision

g. Major repairs

h. Overhaul

**Time Records:** Times should be entered on all pieces of equipment individually to maintain annual totals for the following [Douglas, 1975]:

1. Shift hours
2. Idle time
3. Scheduled hours
4. Downtime
5. Operating hours

A permanent record should also be kept for production by year for each machine. These should be used to analyze performance, determine economic life and replacement timing and obtain the true cost of the machine over its lifetime of useful service.

### **2.1.5 Equipment Replacement**

Replacement is a problem that has plagued equipment owners since the advent of the Industrial Revolution. More particularly, the last two decades of expanding technology have made the problem more urgent. Before the Industrial Revolution, the rate of technological improvement in equipment, as with most durable goods, was very slow. They were generally replaced when they wore out or their physical life ended (i.e. they were no longer able to produce). Life was simple, and it was not necessary to use complex analysis to determine whether or not equipment should be replaced.

Today the situation is entirely different. Modern technology has created obsolescence, and this factor has shortened the economic life of a machine so that it is usually less than its physical life. Consider the definition as illustrated in Figure 2.1, where total profits are plotted against age at replacement for a series of machinery [Jardine, 1973].

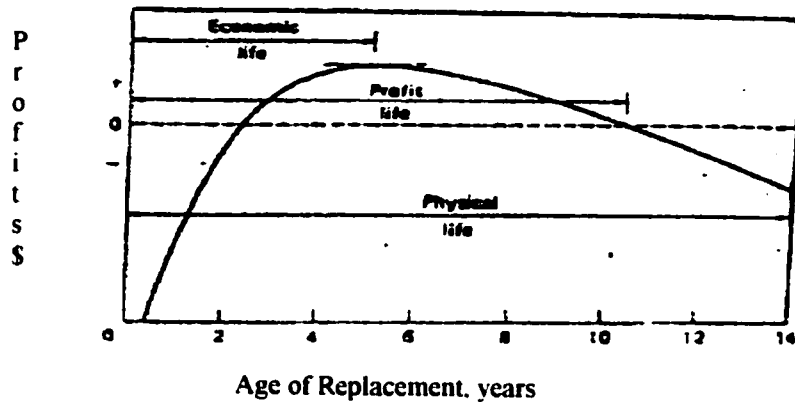


Figure 2.1 Profit Versus Age at Replacement

The physical life is the age at which a piece of equipment is exhausted and can no longer produce; at this point it will usually be abandoned or scrapped. Profit life is the life over which it can earn profit; retention beyond that point will create a loss. The economic life is the life that maximizes profits over the lifetime of the enterprise. The equipment can profitably survive in the face of improved models, changes in methods and techniques, and variable economic influences. The basic definition of economic life has remained unchanged since Taylor's 1923 paper, in which he stated the following [Vorster, 1987]:



All we have to do on this basis is to compute  $X$  (the average annual cost) at the end of each year for the total time the machine has been used up to that date and discard the machine when  $X$  ceases to decrease and begins to increase, provided labor costs and the like have remained constant. If these costs have increased, however, we can well continue to use the old machine after the minimum has been passed. It is then only necessary to compute the unit cost for each year from that point on and discard the machine when the annual unit cost becomes greater than the estimated unit cost for a new machine under the changed economic conditions. The replacement life is defined as the remaining life of the present equipment that optimizes the advantage to the owner.

The replacement decision could be in any of the above stages depending on the required outcome of the replacement.

Equipment replacement problems can be classified as either deterministic or probabilistic (stochastic). Deterministic problems are those in which the timing and the outcome of the replacement actions are assumed to be known with certainty. For example, we may have equipment that is not subject to failure but whose operating cost increases with use. To reduce this operating cost a replacement can be performed.

After the replacement the trend in operating cost is illustrated in Figure 2.2 below:

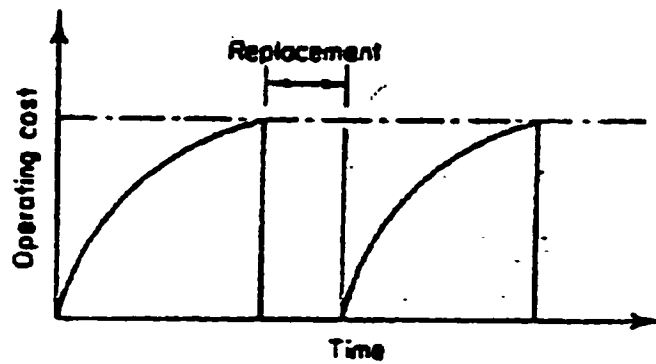


Figure 2.2 Operating Cost Trend After Equipment Replacement

Probabilistic problems are those where the timing and outcome of the replacement depend on chance. In the simplest situation the equipment may be described as being **GOOD** or **FAILED**. A low probability describes changes from **GOOD** to **FAILED**. This may be described by the distribution of time between completion of the replacement action and failure. The time to failure is a random variable whose distribution may be termed the equipment's failure distribution.

Determination of replacement decisions for probabilistically failing equipment involves a problem of decision making under one main source of uncertainty when a failure will occur, or more generally, when the transition from one state of the equipment, either **GOOD** or **FAILED** or somewhere in between, unless a definite maintenance action is taken, such as inspection.

Analyzing the probabilistic problem could be conducted through any quantitative discipline, such as industrial engineering, operational research, or system analysis. These disciplines can assist management in making the replacement decision by using known facts more effectively, by enlarging the proportion of factual knowledge, and by reducing the reliance on subjective Judgment.

One of the benefits of quantitative studies that have been performed in the maintenance area is that factual knowledge, such as the form of the breakdown distribution of various equipment, is becoming available [Jardine, 1973].

The following section will present some of the forms of breakdown distribution for various pieces of equipment that have been developed by Jardine. Each piece of construction equipment is subject to breakdown. By noting the running time to failure of each equipment, it is possible to draw a histogram in which the area associated with any time interval shows the relative frequency of breakdown occurring in these intervals. This is illustrated in Figure 2.3.

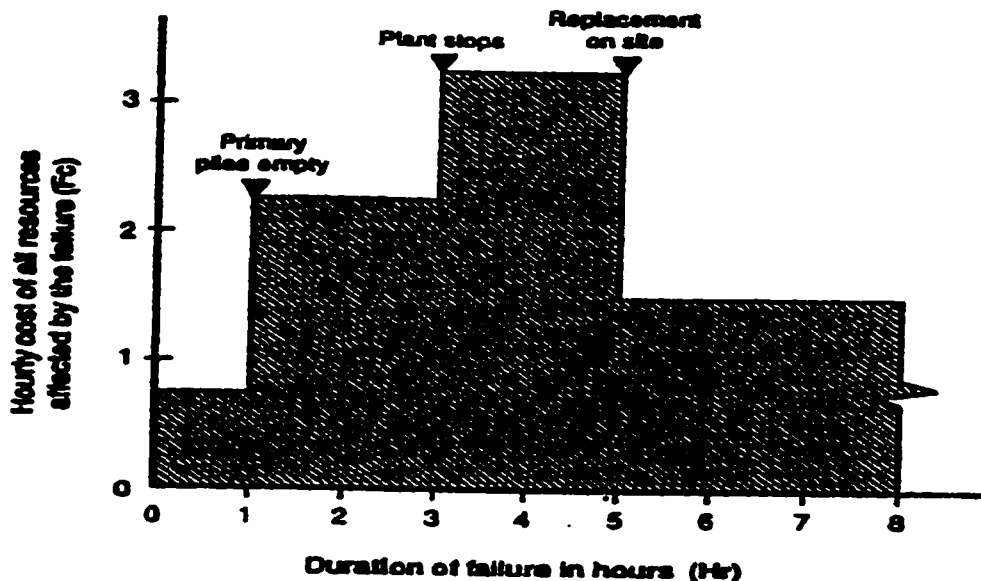


Figure 2.3 Equipment Failure Histogram

If one wishes to determine the probability of a failure occurring between  $t_x$  and  $t_y$  he/she simply multiplies the ordinate  $y$  by the interval  $(t_y - t_x)$ . Further examination of a failure occurring between times  $t_a$  and  $t_z$ , where  $t_a$  is the earliest time and  $t_z$  is the latest time at which the

equipment has failed, is unity. That is, we assume we are certain of the failure occurring in interval  $(t_a, t_z)$ . The area of the histogram equals one.

In maintenance studies we tend not to use relative frequency histograms but rather the density function. The reason for this is that the density function is more easily managed. Probability density functions are similar to relative frequency histograms except that a continuous curve is used, as illustrated in Figure 2.4 below. The equation of the curve of the density function is denoted by  $f(t)$ .

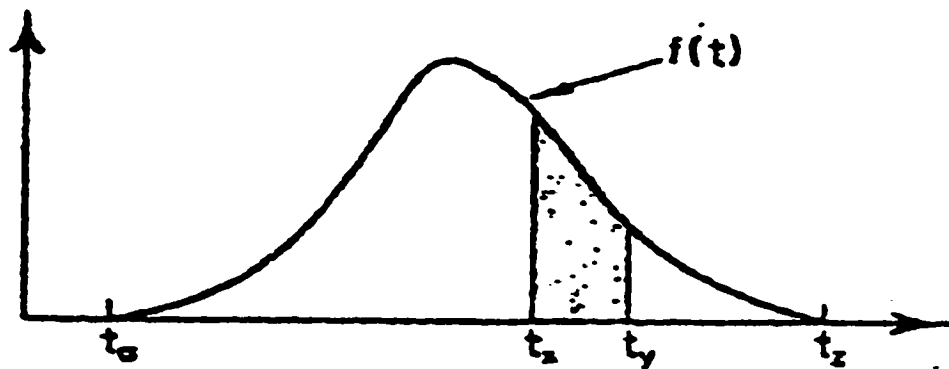


Figure 2.4 Equipment Failure Curve

The probability of a failure occurring between times  $t_x$  and  $t_y$  is the area of the shaded portion of the curve. Using calculus, this area is the integral between  $t_z$  and  $t_y$  of  $f(t)$ , namely

$$\int_{t_z}^{t_y} f(t) dt \quad (1)$$

The probability of a failure occurring between times  $t_z$  and  $t_y$  is then

$$\int_{t_a}^{t_z} f(t)dt \quad (2)$$

Needless to say, the failure characteristics of different equipment are not the same. Even the failure characteristics of identical equipment may not be the same if they are operating in different environments.

There are a number of well-known probability density functions that have been found in practice to describe the failure characteristics of equipment. Some of them are illustrated in Figure 2.5 below:

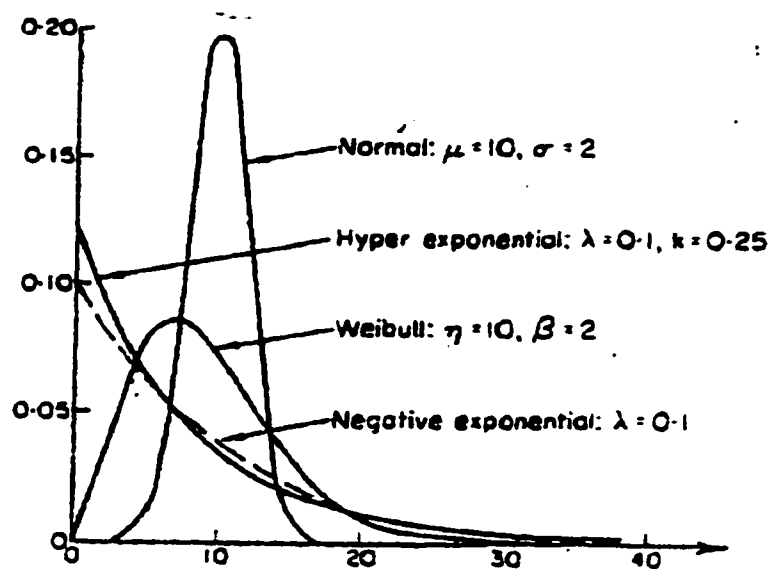


Figure 2.5 Failure characteristics for some types of equipment

The equations of the four density functions illustrated along with some examples of where these distributions have arisen are as follows:

### **1. Hyper-Exponential Distribution:**

When equipment has failure times that may be very short or very long, its failure distribution is frequently represented by the hyper-exponential distribution. Some electronic computers have been found to fail according to this distribution. The density function of the hyper-exponential distribution is as follows:

$$f(t) = 2k^2\lambda \exp[-2k\lambda t] + 2\lambda(1-k)^2 \exp[-2(1-k)\lambda t] \quad (3)$$

Where  $t \geq 0$  with  $0 < k \leq 0.5$ ,  $\lambda$  is the mean arrival rate of breakdown, and  $k$  is a parameter of the distribution.

### **2. Negative Exponential Distribution:**

The negative exponential distribution is one that arises in practice where failure of equipment can be caused by failure of any one of a number of components of which the equipment is compromised. Also, it is a characteristic of equipment subject to failure due to random causes such as sudden excessive loading. The distribution is found to be typical for many electronic components and pieces of industrial equipment. The density function is

$$f(t) = \lambda \exp [-\lambda t] \quad \text{for } t \geq 0 \quad (4)$$

Where  $\lambda$  is the mean arrival rate of breakdowns and  $1/\lambda$  is then the mean of the distribution.

### **3. Normal Distribution:**

The normal or Gaussian distribution applies, for instance, when a random effect (for example time to failure) is the consequence of a large number of small and independent random

variations. When this is true for the time to failure, the failure distribution becomes a bell-shaped, normal distribution.

In practice, lamps and bus engines are two types of equipment that have been found to fail according to a normal distribution. The density function for the normal distribution is

$$f(t) = 1/\sigma \sqrt{2\pi} \exp[-(t-\mu)^2 / 2\sigma^2] \text{ for } -\infty \leq t \leq \infty \quad (5)$$

Where  $\mu$  is the mean of the distribution and  $\sigma$  the standard deviation.

#### 4. Weibull Distribution:

The Weibull distribution is an empirical distribution that appears to fit a large number of failure characteristics of equipment. One of the original papers on the application of the Weibull distribution to equipment failure times related to electron tubes. The density function of the Weibull distribution is as follows:

$$f(t) = (\beta / \eta) * (t/\eta)^{\beta-1} \exp [-(t/\eta)^\beta] \text{ for } t \geq 0 \quad (6)$$

Where  $\eta$  is a scale parameter (sometimes termed characteristic life),  $\beta$  is a shape parameter, and  $\eta$  and  $\beta$  are positive.

Using the above density functions, we can derive and analyze the equipment's behavior toward the following facts:

1. To obtain the probability of a failure occurring before some special time, say  $t$ . This probability can be obtained from the relevant probability density function as follows:

$$\text{Probability of failure before time } t = F(t) = \int_{-\infty}^t f(t) dt \quad (7)$$

2. The reliability function, sometimes termed the survival function, is determined from the probability that equipment will survive at least to some time  $t$ . The reliability function is denoted by  $R(t)$  and is defined as follows:

$$R(t) = \int_t^{\infty} f(t) dt \quad (8)$$

3. To obtain the failure rate of the equipment. The failure rate of a piece of equipment is the ratio of the number of items that fail in an interval of time (say one week) to the number of the original population that was operational at the start of the interval. Thus, the failure rate of a piece of equipment at time  $t$  is the probability that the equipment will fail in the next interval of time given that it is good at the start of the interval, i.e. it is a conditional probability.

So the instantaneous failure rate (or hazardous rate or force of mortality) is defined as follows:

$$r(t) = \frac{f(t)}{1 - F(t)} \quad (9)$$

## 2.2 EQUIPMENT REPLACEMENT POLICY

The equipment replacement policy is the procedure or practice that is followed to monitor owned construction equipment performance, total cost, and the company need for additional construction equipment in order to come up with the best replacement decision that maximize the total profit and reduce the expenses and losses. It is a regular quantitative analysis that is required to control and balance the equipment need and usage. Companies might need the policy to replace inefficient equipment, inadequate equipment, or to add equipment to satisfy growing demand. A written policy or equipment replacement manual is desired because it is very important to make the replacement procedure clear, stipulated, and well documented. This helps



to improve and modify the procedure whenever required. It also helps the company personnel to be familiar with the replacement procedure.

Some of the factors that necessitate the need for written equipment replacement manual or policy include (National Association of Accountants, 1965):

1. Cost and complexity of individual equipment is real high.
2. Number of available and needed construction equipment is high.
3. Sizes of construction contracts that are undertaken are large and require considerable number of equipment to be used.
4. Availability of new models that are advanced and might improve the productivity and reduce the total cost.
5. Competition with others and position in the local market.

The equipment replacement policy consists of the elements or requirements that need to be evaluated in order to make effective and profitable equipment replacement decisions. These requirements are as follows:

1. Forecasting the economic background:

As a requirement for the replacement decision, management needs to study the company's opportunity for profitable use of the equipment in question. Following are the main factors influencing such opportunities:

- a. General level of business activity
- b. The future of the industry
- c. The future of the company
- d. The company's need for facilities and personnel

## **2. Long range planning:**

Long range planning comprises the determination of company objectives and the selection of courses of actions that are consistent with achievement of the objectives.

## **3. Identification of the alternatives:**

Identification of the alternatives is very important for equipment replacement. This doesn't mean listing the new equipment models and selecting among them. It includes the study of available alternatives that may be considered before a decision is made. These alternatives are as follows:

- a. Remodel the present equipment
- b. Lease another one
- c. Buy a used one
- d. Buy a new one
- e. Continue with the old equipment
- f. Discontinue the procedure altogether

## **4. Time span covered by replacement decision:**

Another aspect of long range planning for equipment replacement is determination of the future time period for which replacement plans are to be developed.

## **5. Evaluation of equipment replacement proposals:**

All the required input data or controlling factors for each alternative will be assessed prior to the evaluation of the proposals. The evaluation process will then start depending on the decision criteria that are set and used by the firm.

The following sections will discuss the factors that affect the replacement decision and commonly used equipment replacement methods.

## **2.3 FACTORS AFFECTING THE REPLACEMENT DECISION**

The factors that affect the equipment replacement decision can be classified into two groups: those that specifically relate to the equipment and its proposed replacement and those related to the national economy and the pertinent fiscal environment. Examples of the first group include the initial cost, expenses of downtime, repairs, maintenance, and obsolescence costs. Under the second group, the most important factors are the interest and inflation rates.

Following is a detailed discussion of some of these controlling factors.

### **2.3.1 Ownership Cost**

Ownership costs are those expenses that the owner of a piece of equipment must take into account to evaluate and protect his investment. The ownership costs usually accrue whether or not the equipment is actually used, so it becomes very important to maximize the utilization of all such equipment. This cost could be divided into the investment cost and the depreciation cost.

#### **a. Investment Cost**

The investment cost is how much the investment cost the owner. It includes the interest on the money invested, taxes of all types (which are assumed against the equipment), insurance, and storage. It often includes sometimes the major repair and overhaul costs. The rates for these items will vary somewhat among different owners based on location and other factors. There are several methods of determining the cost of interest paid on the money invested in equipment. Even though the owner pays cash for the equipment, he should charge interest on the investment, as the money spent for the equipment could be invested in other assets that would return interest to the owner.

Some equipment owners charge a fixed rate of interest against the full purchased cost of the equipment each year it is owned. This method provides an annual interest cost that is higher than it should be. One realistic approach is that for each year the equipment is used, the owner should deduct from its earning an amount equal to the annual cost of depreciation. After the equipment has been used for the estimated depreciation period, expressed in years or units of production, the owner will have recovered its original cost through the reserve for depreciation.

The average annual value of the equipment then can be calculated by knowing the values of the equipment for the beginning of each year that it will be used. After this is determined, use one of the following formulas [Peurifoy, 1985]:

$$P^* = \frac{P(N + 1)}{2N} \quad \text{when there is no salvage value} \quad (10)$$

$$P^* = \frac{P(N + 1) + S(N + 1)}{2N} \quad \text{when there is estimated salvage value} \quad (11)$$

Where:  $P^*$  = the annual average value of the equipment;  $P$  = the total initial cost of the equipment;  $N$  = the life of the equipment in years;  $S$  = the salvage value of the equipment

It is common practice to combine the cost of interest, insurance, taxes, and storage and to estimate them a fixed percent of the average annual value of the equipment.

#### **b. Depreciation Cost:**

Depreciation is the loss in the value of the equipment over time. This is generally caused by wear and tear from use, deterioration, obsolescence, or reduced need. The owner of the equipment must recover this loss of value during its useful life.

The general term “depreciation” should not be confused with the specific term “depreciation accounting.” Depreciation accounting is the systematic allocation of the costs of capital

investment over some specific number of years. Following are reasons for calculating the depreciation accounting value (usually termed the book value) of a piece of equipment:

1. To provide the construction owner and project manager with an easily calculated “estimate” of the current market value of the equipment. To do this the method of depreciation accounting selected should approximate market value.
2. To provide a systematic method for allocating the depreciation portion of equipment ownership costs over a period of time and to a specific productivity rate.
3. To allocate the depreciation portion of ownership costs in such a manner that the largest tax benefits accrue.

depreciation can be calculated using one of the four common methods. These are the Straight Line Method, Sum of Years Method, Declining Balance Method, and the Sinking Fund Method. To calculate the depreciation by any of these methods a close estimate of the following items is required:

1. The purchase price of the equipment, termed  $P$
2. The economic life of the equipment (the optimum period of time to keep the equipment), or the recovery period allowed for income tax purposes, termed  $N$
3. The estimated resale value of the equipment at the close of the economic life, known as the salvage value, termed  $S$ .

#### **1. The Straight Line Method:**

Straight-line (SL) depreciation is the easiest method to calculate the depreciation amount or rate and is probably the most widely used method in construction. The annual amount of depreciation  $D$  for any year  $m$  is a constant value, and thus the book value  $BV_m$  decreases at a uniform rate

over the useful life of the equipment. The equations for this method are as follows [Peurifoy, 1985]:

$$\text{Depreciation Rate, } R_m = 1/N \quad (12)$$

$$\text{Annual Depreciation Amount, } D_m = R_m(P-S) = (P-S)/N \quad (13)$$

$$\text{Book Value at Year } m, BV_m = P - mD_m \quad (14)$$

### 3 Sum of Years Method:

The sum of years method is an accelerated method (fast write-off), which is a term applied to accounting methods that permit rates of depreciation faster than the straight line. The rate of depreciation is a factor times the depreciable value (P-S). This factor is determined as follows:

- a. The denominator of the factor is the sum of the digits or years (SOY) including the first through the last year of the life of the equipment. Thus, [Peurifoy, 1985]

$$SOY = \frac{N(N+1)}{2} \quad (15)$$

- b. The Depreciation Rate,  $R_m$  is

$$R_m = \frac{N - m + 1}{SOY} \quad (16)$$

- c. The annual depreciation,  $D_m$  for the mth year (at any year m) is

$$D_m = R(P-S) \quad (17)$$

- d. The Book Value  $BV_m$  at the end of year m is

$$BV_m = P - (P-S) \left[ \frac{m(N + m / 2 + 0.5)}{SOY} \right] \quad (18)$$

### 3. Declining Balance Method:

The declining balance method is also an accelerated depreciation method that provides for even larger portions of the cost of a piece of equipment to be written off in the early years. Interestingly, this method often more nearly approximates the actual loss in market value with time.

Declining methods range from 1.25 times the current book value divided by the life to 2 times the current book value divided by the life (the latter is termed Double Declining Balance).

Note that although the estimated salvage value  $S$  is not included in the calculation, the book value cannot go below the salvage value. Following are the equations necessary to use the declining balance method of depreciation [Peurifoy, 1985]:

1. The Depreciation ratio ( $R$ ) for the respective decline balance value can be estimated as:

- a. For 1.25 declining balance (1.25DB) method,  $R = 1.25/N$
- b. For 1.50 declining balance (1.5DB) method,  $R = 1.5/N$
- c. For 1.75 declining balance (1.75DB) method,  $R = 1.75/N$
- d. For double declining balance (DDB) method,  $R = 2/N$

2. The allowable depreciation  $D_m$  for any year  $m$  and any depreciation rate  $R$  is

$$D_m = R P (1-R)^{m-1} \quad (19)$$

3. The book value for any year  $m$  is

$$BV_m = P(1-R)^m \quad \text{provided that } BV_m \geq S \quad (20)$$

#### **4. Sinking Fund Method:**

The sinking cost method is used when money is put away in equal periodic installments, usually each year, to earn interest. At the end of the equipment's useful life, the value of the fund should equal the equipment's original value. Thus, there will be money available from the sinking fund at the end of the useful life. The scheme is that this money will be used to replace the equipment when it has served its useful life. Therefore, there are two assumptions to be made when the sinking fund method is used. The first assumption is that an amount of money equal to the original cost of the equipment will be sufficient to replace it at the end of its useful life. The second assumption is that the earning power of the money in the fund, represented by the interest rate, will be the same during the life of the fund [Day, 1973].

Using the two assumptions stated above, the equal periodic payments,  $a$ , to the sinking fund would be as follows:

$$a = S_f [ I / (1+I)^u - 1 ] \quad (21)$$

Where:  $S_f$  = sinking fund to be accumulated;  $I$  = annual interest rate to be earned by the fund;  $u$  = the equipment life in years.

The depreciated value of the equipment at any time will be the original value minus the installments and the interest that they have earned up to that time. Thus, the depreciation charge for any one year is equal to the periodic payment,  $a$ , plus the interest earned in the sinking fund during the past year.

The four depreciation methods mentioned above can be represented graphically as shown in Figure 2.6 below.



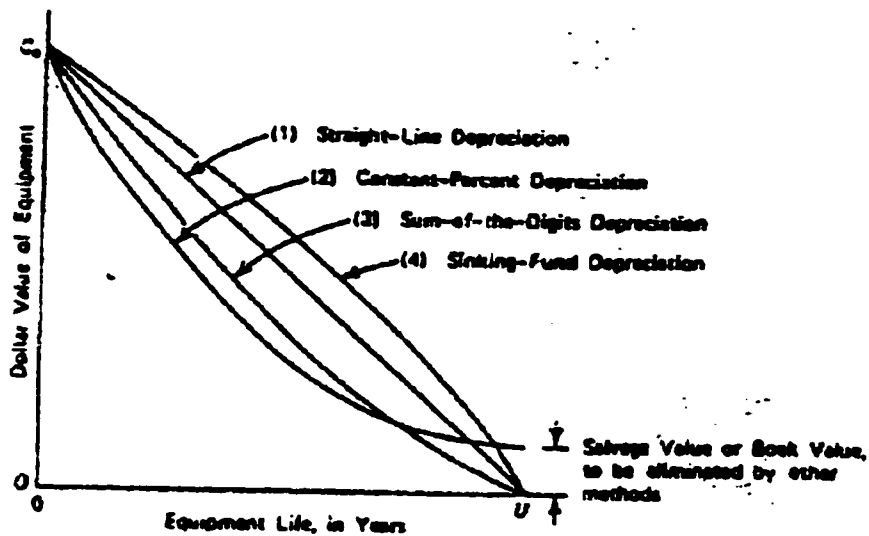


Figure 2.6 Comparison of the Four Depreciation Methods

In each method the charge is often made just once a year, usually at the end of each year of useful life or at most each month. Consequently, the graph of each method should be a stepped line. However, for clarity in analyzing the advantages and disadvantages of these methods each successive depreciated value is connected by a smooth curve. These curves are based on no salvage value.

### 2.3.2 Operating Cost

Operating costs are those costs associated with the operation of a piece of equipment. In contrast to the ownership costs, which generally accrue whether or not the equipment is actually being used, operating costs usually accrue only when the equipment is being used. Operating costs include fuel and lubrication costs, operator costs, and minor maintenance and repair costs. The other costs involved with a piece of equipment are major maintenance, major repair, and

tires/treads. These costs are sometimes included in the ownership cost and sometimes in the operating cost. Either way, they represent a significance cost category and should not be overlooked.

### **2.3.3 Salvage Value**

The salvage value of equipment is its reasonable market value at some future date of disposal. It may include a dismantling charge or removal charges if applicable. Past practice is the best guide for establishing the salvage value, and the contractor's previous experience is generally given some weight in the determination.

### **2.3.4 Time Value of Money**

Today almost everyone is aware of the fact that money has a time value. One dollar today is worth more than one dollar tomorrow. This means that the use of a certain amount of money generates a charge (cost) against that money. So, if a firm takes a loan from the bank, the return of the invested money should be equal to or greater than the cost of the loan to be attractive. When a bank lends money, it makes a time charge that is called interest. Interest charges (rates) are made at the end of a time period (usually a year). These interest charges may be considered as a rented rate for the use of the money. When these interest rates are made the total amount will bear interest at the end of the next time period. This procedure is known as compounding. Compounded interest is the interest rate charged on the total amount of principal and interest for the previous time period.

To aid in identifying and recording the economic effects of investment alternatives, a graphical description of each alternative's cash transactions may be used. This graphical descriptor,

referred to as cash flow diagram, can provide the information necessary for analyzing a replacement proposal. A cash flow diagram represents receipts during a period of time by an upward arrow (an increase in cash) located at the period's end. The arrow height may be proportional to the magnitude of the receipts during that period. Similarly, disbursements (costs) during a period of time are represented by a down ward arrow (a decrease in cash). These arrows are then placed on a time scale that spans all time periods covered by the proposal.

The net cash flow is the arithmetic sum of the receipts (+) and the disbursements (-) that occur at the same point in time.

To facilitate describing the investment cash flows, the following notations will be adopted;

- $i$  = the annual interest rate;
- $n$  = the number of annual interest periods or the number of investment periods;
- $P$  = the present worth for a present or future expenses and revenues;
- $A$  = the annual equivalent for a present or future expenses and revenues;
- $F$  = the future worth for a present or future expenses and revenues.

The present value of certain future amount of money can be found using the formula;

$$P = F / (1+i)^n \quad (22)$$

Where  $1 / (1+i)^n$  is known as the single-payment present-worth factor and is designated as  $(P/F, i, n)$ .

The same equation above can be restated to determine the future value of a present sum as follows;

$$F = P (1+i)^n \quad (23)$$

Where  $(1+i)^n$  is known as the single-payment compound-amount factor and is designated as  $(F/P, i, n)$ .

The equal-payment-series compound-amount  $A$  for a future value can be found as;

$$A = F[i / (1+i)^n - 1] \quad (24)$$

Where  $[i / (1+i)^n - 1]$  is known as the equal-payment-series sinking-fund factor and is designated as  $(A/F, i, n)$ .

The equal-payment-series compound-amount  $A$  for a present value can be found as;

$$A = P[i (1+i)^n / (1+i)^n - 1] \quad (25)$$

Where  $[i (1+i)^n / (1+i)^n - 1]$  is known as the equal-payment-series capital-recovery factor and is designated as  $(A/P, i, n)$ .

### **2.3.5 Inflation**

Inflation is the result of an excess of money and available credit over the supply of goods. This future dollars is to buy an equal amount of a given commodity, whether a material or a service. The money problems created by inflation result from the combination of dollars of different years when they are not of equal value. This occurs primarily in depreciation accounting, tax computations for gain on sale, and loan interests. The first two work to the disadvantage of the equipment owner while the latter is to his advantage.

To date, there is no reliable index available to measure the total effect of costs on equipment ownership and operation. The Consumer Price Index (CPI) is the most common measure and is generally used on union agreements regarding wages to determine cost of living increases. Other price indexes measure other mixes of labor and materials. Some of the best known are the

Wholesale Price Index (WPI), the Engineering News-Record Cost Indexes (Building and Construction) (ENR), and the Federal Highway Administration Bid Price Index (FHWA).

### **2.3.6 Deterioration and Obsolescence**

Deterioration is typically expressed by increasing operating cost and decreasing resale value of the equipment. Obsolescence is the economic inferiority created in an old piece of equipment by the interdiction of an improved model. It tends to improve revenues and reduce costs, as newer and better machines are made available. As a result of employing improved equipment, the contractor is able to make more profit. The effect of obsolescence on equipment is to reduce its economic life, i.e. the life that maximizes its profit potential.

Obsolescence can affect the value of equipment through several agents. One is the loss in revenue when the present equipment is threatened by a newer, more productive model. Another agent affecting equipment economics is the reduced cost of maintenance and operation due to improvements in the replacement equipment.

Terborgh said that deterioration is a characteristic of the existing machine itself, while obsolescence is a characteristic of the new challenger. Smith pointed to two types of obsolescence. Market obsolescence refers to the loss in profitability of a product or service due to the fact that the system used to produce it yields an output less marketable than that produced by an available production system. The other is cost obsolescence, which can be used to describe what was identified by Terborgh as higher production costs due to the fact that the system used to produce a good or service does so at a higher cost than a newer, available production system.

[Meyer, 1993]

### **2.3.7 Consequential Costs**

Equipment costs are normally divided into two categories: ownership cost and operating cost. A third category, consequential cost, may be defined to cover the intangible costs arising from the fact that equipment often performs less well than expected and thereby impacts many aspects of the production process.

Many authors mention consequential costs. The basic premise is that equipment failure forces construction supervisors to change previously established and presumably optimal construction plans. It is these charges that give rise to consequential costs. Early treatment of the consequential cost phenomenon uses terms such as “Payroll during delays caused by breakdown” (Van Duzer 1930), while others define a component called “downtime cost” as part of the operating cost (Caterpillar 1969). Nunnally (1977) stated the following: “One method of assigning downtime cost to a particular year of equipment life is to use the product of the estimated percentage of downtime multiplied by the planned hours of operation for the year multiplied by the hourly cost of a replacement or rental machine.”

Cox (1971) calculates the cost of “interruption caused by component failure” as being the product of the annual frequency of component failure, the average time to replace the component, and the total cost of the team affected by the failure. [Vorster, 1987]

### **2.3.8 Failure Cost Profile**

The failure cost profile is a diagram designed to show how the total cost of all the resources are affected by the failure of one member of a production team over the duration of the failure. An example is given in Figure 2.7 using costs aggregated on an hourly basis.

Machine (1)	Assignment				
	a1 (2)	a2 (3)	a3 (4)	a4 (5)	a5 (6)
M1	0.65	0.80	0.90	0.65	1.00
M2	0.70	0.80	1.00	0.70	1.00
M3	0.70	0.80	1.00	0.70	1.00
M4	1.00	1.00	1.00	1.00	1.00

Figure 2.7 Failure Cost Profile

From Figures 2.7 and 2.3 the following can be noted:

- The diagram is unique to a particular machine type, M
- The diagram is unique to a particular application shown by the second lower case letter (a)
- The vertical scale, Fc, shows the hourly cost of all resources affected by the failure of a particular machine type in a particular application,  $Fc_{Ma}$ . It is measured as the multiplier of the standard owning and operating cost for a given machine type in order to accommodate any changes due to inflation in the basic equipment cost.
- The horizontal axis, Hr, measures the duration of the failure in working hours

The failure cost profile for a particular equipment in a particular application,  $FCP_{Ma}$ , is given by the variation of  $Fc_{Ma}$  as the duration of the failure increases:

$$FCP_{Ma} = f(Fc_{Ma}, Hr) \quad (26)$$

It can be seen that the equation above differs from the methodology proposed by Nunnally in that Fc includes all the affected resources (not only the failed equipment) and FCP varies with Hr. In addition, the equation varies from the methodology proposed by Cox in that FCP can vary with time as the impact builds or as action is taken to reschedule the productive teams.

## **2.4 EQUIPMENT REPLACEMENT METHODS**

There are many quantitative models that have been developed and used to evaluate the equipment replacement need and to derive numerical values for the decision criteria that help management make the right replacement decision. The models are grouped depending on the model's output or conclusion. These groups or model conclusions are called the equipment evaluation criteria and include the net present value, the annual cost minimization, the total cost minimization, the payback period, the internal rate of return, the economic life, and the profitability index method.

The following material will discuss in more detail these evaluation criteria and will present the most popular models in each group.

### **2.4.1 The Net Present Value (NPV) Method**

The Net Present Value (NPV) is the net equivalent amount at the present time that represents the difference between the equivalent expenses and the equivalent revenues for an alternative's cash flow for selected interest rate and investment duration.

The prime objective for the method is to indicate if the alternative is profitable and worth the investment or not. The method concentrates the equivalent value of any cash flow in a single index at a particular point in time ( $t=0$ ). In addition, a single unique value of the present worth is associated with each ( $i$ ) used, no matter what the investment's cash flow pattern may be.

The common approach for calculating the NPV is to find the present worth or value for each future revenue or expense and summing them at the present time. [Thuesen, 1993]

Letting  $F_t$  be the cash flow at time  $t$  (it will be positive for revenues and negative for expenses), the NPV of an alternative at interest rate ( $i$ ) with a life of ( $n$ ) years can be expressed as:



$$NPV = F_0 (P/F, i, 0) + F_1 (P/F, i, 1) + \dots + F_n (P/F, i, n) \quad (27)$$

Where  $(P/F, i, n)$  is the known as the single-payment present-worth factor and equal  $1 / (1+i)^n$ .

Or

$$NPV = \sum_{t=1}^n F_t(1+i)^{-t} \quad (28)$$

The NPV method only indicates if the proposal is profitable or not. When the proposal NPV is positive, the proposal promises an acceptable rate of return and considered profitable. If the NPV is negative, the proposal is considered non-profitable one.

The conventional presentation of this net present value (NPV) is [Beaves, 1993]:

$$NPV = \sum_{t=0}^N \frac{a_t}{(1+k)^t} \quad (29)$$

Where:  $a_t$  is the expected net cash flow at time  $t$ ;  $k$  is the discount rate

If a replacement proposal has a positive present worth when it's cash flow curve discounted at such a rate, the investment promises an acceptable rate of return. This method will only indicate if the proposal is profitable (positive Net Present Value, NPV) or not profitable (negative NPV).

Another form of the discount rate is  $k$ , which is shown in equation 23. This discount rate represents the firm's periodic opportunity cost for  $n$  period horizon over which the project is being evaluated. For interim cash flows that have at least one non zero net cash flow, the opportunity cost is referred to as the reinvestment rate [Beaves, 1993].

The discount rate is often referred to as the minimum attractive rate of return, cutoff rate, hurdle rate, or marginal growth rate, among others [Lohmann, 1988].

Selection of the discount rate has been discussed by both theorists and practical businessmen, but no general agreement has been reached. The following two general concepts have been advocated:

1. A rate that represents the cost to the company of procuring capital, sometimes called the borrowing rate.
2. A rate that represents the company's opportunity cost or capital or the rate that can be earned in the best alternative use of the same fund. This is sometimes called the lending rate.

Discount rate tables are good references for obtaining pre-calculated discount rate values.

Following is a summary of the research and models that use the NPV as replacement decision criteria:

#### **a. Hotelling's Model**

Hotelling (1925) proposed the following model [Jaafari, 1990]:

$$V_o = \int_0^n [Z * Q(t) - O(t)] * E^{-it} * S * E \quad (30)$$

Where  $V_o$  = present value of the machine;  $E = e^{-it}$ ;  $n$  = number of years of machine life;  $Z$  = selling price of a unit of output;  $Q(t)$  = units of output in year  $t$ ;  $O(t)$  = operating costs incurred during year  $t$ ;  $e$  = base of the natural logarithm;  $i$  = current interest rate;  $S$  = machine's salvage value at year  $N$ .

Although Hotelling recognized the existence of machine obsolescence due to technological improvements in future replacement, he made no allowance specifically for it in his model. The model also considers only the existing machine and ignores the effect of improvements in future replacements. He suggested that the obsolescence cost caused by technological improvement be charged as additional operating expenses, which is similar to an insurance premium.

## b. The Incremental Wealth Model

Beaves (1993) presented the incremental wealth model, which views the NPV as the difference between the initial wealth  $W_0$  and the present value of the terminal wealth  $W_n$  attributable to a project. The incremental wealth view is represented by the following formula:

$$NPV^* = \frac{W_n}{(1+k)^{**n}} - W_0 \quad (31)$$

Without a reinvestment assumption,  $W_0$  and  $W_n$  are uniquely determined only for projects that have no intermediate cash flows. The incremental wealth model was generalized to projects that have intermediate cash flows with the assumption of a reinvestment rate as follows:

$$W_0 = - \sum_{t=0}^{i^*} \frac{at}{(1+r_{0,t})^{**t}} = - P_t^* \quad (32)$$

$$W_n = \sum_{t=t^*+1}^n a_t (1+r_{t,n})^{n-t} \quad (33)$$

$$NPV = \frac{\sum_{t=t^*+1}^n at(1+rt,n)^{**n-t}}{(1+k)^{**n}} + \sum_{t=0}^{i^*} \frac{at}{(1+r_{0,t})^{**t}} \quad (34)$$

The generalized incremental wealth model is less restrictive and overcomes such issues as mixed projects, reinvestment assumptions, multiple rates of return, and ranking inconsistencies between net present value and rate of return criteria.

### c. The Strategic Replacement Model

Meyer (1993) proposed the strategic replacement model that formulates the salvage value and the operating costs as a function of both age and commutative equipment use due to the effects of differing demand levels. The model is as follows:

$$PEX(N) = -B + V(N, cu(N)) (P/F, i, N) + \left[ \sum_{n=1}^N (d(n)p(n) - aroc(n) - UROC(n)) (P/F, i, n) \right] \quad (35)$$

Where the following assumptions are made:

1. The commutative use,  $c(u)$ , is defined as a function of the demand  $d(n)$  as

$$c(u) = \sum_{t=1}^n \pi d(t)$$

2. The salvage value,  $V$ , is modeled as a function of age of the equipment,  $N$ , and commutative use as  $V(N, cu(N))$
3. The operating expenses are modeled as a combination of two cost functions. The age related operating costs,  $aroc$ , are those costs dependent only on time, such as floor space, insurance, and some kind of preventive maintenance. The other one is the use related operating cost,  $uroc$ , which are those costs that are dependent on the amount of equipment use, such as energy and repair costs. The  $UROC(n)$  is the integral of  $uroc$  over the period of use.
4. Revenues are modeled as the product of the demand,  $d(n)$ , and price,  $p(n)$ , in order to incorporate the effect of competitive advantage.

5. PEX is the before-tax present value of the net cash flow, B represent the initial cost of the equipment, and i is the rate of return on capital.

### **2.4.2 The Internal Rate of Return (IRR) Method**

The internal rate of return (IRR) is the interest rate that causes the equivalent revenues of a cash flow to equal the equivalent expenses. In other ways, it is the interest rate (i) that reduces the present worth of a series of revenues and expenses for the cash flow to zero. In economics, the IRR represents the percentage or rate earned on the unresolved balance of the investment.

The conventional presentation for the IRR is the discounted form, which equates the present worth of proposed cash outlays to the present worth of the cash inflows. It discounts to zero the net cash flows associated with a given investment. The IRR is (i) that satisfy the following equation [Thuesen, 1993]:

$$NPV(i) = \sum_{t=1}^n F_t(1+i)^{-t} = 0 \quad (36)$$

The IRR is the smallest number (i) that satisfy equation (36). The number represents the minimum interest rate that can be gained from the replacement process for the estimated investment period.

The internal rate of return is a significant measure of investment worth because it relates the amount of saving or earnings to both the amount of capital employed and to the time this capital is in use. The internal rate of return (IRR) from a proposed replacement can be compared with the target rate of return that management considers necessary to justify new investment in the business.

There are two ways to calculate the rate of return. These two ways are the Financial Statement Method and the Discounted Cash Flow Method.

The rate of return calculated using the financial statement method is based on the investment capital and the amount of annual saving. Since the basic data are determined by accounting procedures employed for determining periodic net profit and financial condition, this method is commonly called the financial statement method or the accounting method.

Numerous variations are possible in determining the amount of investment and savings by this method for some basic set of facts. For example, the gross book value of assets or the average net book value may be designated as the amount of investment. They can also be determined using first year savings or average annual saving. These will impact the calculated rate or return.

Some of the advantages of this method are its simplicity and ease of understanding, but this method discards the time value of money and requires excessive knowledge of accounting to determine a project's investment and savings.

The discounted cash flow method equates the present worth of proposed cash outlays to the present worth of cash inflows. It discounts to zero the net cash flows associated with a given investment. This method is commonly called the discounted cash flow method, although other terms include investor's method, profitability index, internal rate of return, and time adjusted rate of return.

The discounted rate of return differs from the financial rate of return method in two important respects:

- a. It is calculated from incremental cash flows over the whole life of the proposed replacement since estimates of costs and revenues are prepared on a cash basis rather than on an accrued basis.

- b. It uses the time value of money concept

These two characteristics make the discounted cash flow rate of return more reliable than the financial statement rate of return.

Following are some of models that calculate the IRR using the discounted cash flow method:

#### **a. MAPI Model**

Terborgh (1949) and his research associates at the Machinery and Allied Products Institute (MAPI), United States, introduced a method that explicitly attempted to account for the relative “functional degradation” between an existing piece of equipment and its successor due to technological improvements. [Jaafari & Mateffy, 1993] The MAPI model is as follows:

$$R = \frac{A + B - C}{D} \times 100 \quad (37)$$

Where R = the after tax rate of return; A = coming year's new operating advantage resulting from the use of the new equipment; B = net capital consumption for the coming year; C = income tax payable in the next year; and D = net capital investment.

The MAPI model, according to the National Association of Accountants (NAA) ('Financial' 1965), has not been used widely despite the MAPI charts and tables that facilitate computation of R. NAA offers the following reasons.

1. Requires too much information
2. Calculations result in high rates of return, which always make replacements seem desirable.
3. Gives too much emphasis to the rate of return, which might not be the primary objective of the replacement decision.

4. Is very academic and sophisticated.

### **b. Required Margin Method**

Connor and Evans (1972) developed the required-margin method, which is somewhat similar to the MAPI method. In this method, a minimum rate of return  $R_r$  that one should expect from a replacement investment is first determined using prepared tables.  $R_r$  is then compared with the estimated rate of return  $R_o$  of a replacement investment proposal. If the investment has a greater return, it may be recommended [Jaafari & Mateffy, 1993].

### **c. The Incremental Wealth Method**

As a continuation of the incremental wealth model that was proposed by Beaves (1993) and discussed in Section 2.4.1., Beaves also proposed a formula to calculate the IRR as follows:

$$IRR = \left[ \frac{W_n}{W_o} \right]^{1/n} - 1 \quad (38)$$

This model was generalized to projects that have intermediate cash flows with the assumption of a reinvestment rate as follows:

$$IRR = \left[ \frac{\sum_{i=0}^n yi(1+r)^{n-i}}{\sum_{i=0}^n -ci(1+r)^{n-i}} \right]^{1/n} - 1 \quad (39)$$



The generalized incremental wealth model is less restrictive and overcomes such issues as mixed projects, reinvestment assumptions, multiple rates of return, and ranking inconsistencies between net present value and rate of return criteria.

### 2.4.3 The Payback Period (PBP) Method

The payback period is the period of time after which the investor will recover his money. Normally, the owner will set a required number of years where the proposed equipment is accepted if its payback period is less than the predetermined number. The payback period is widely used as a measure of the investment worth because of its seeming simplicity. It is traditionally determined by dividing the purchase price of the new equipment by the estimated savings over the use. For example, if the annual saving of the equipment is SR 725 and the purchase price of the equipment is SR 16,000, the resulting payback period is approximately equal to  $16,000/725 = 22$  years.

The conventional presentation for the PBP method is the discounted form that use the NPV formula as a base for the calculations. The discounted PBP is the minimum number of years (n) that satisfy the following equation [Thuesen, 1993]:

$$NPV(n) = \sum_{t=1}^n Ft(1+i)^{-t} \geq 0 \quad (40)$$

The traditional PBP criterion did not account for the time value of money. Later, the time factor was taken into account, which led to the following definition of so-called discounted PBP [Hajdasinski, 1993]:

$$NPV(k) = \sum_{j=0}^k b(j) (1+i)^{-j}, \quad k=0,1,2,\dots, n \quad (41)$$

Where  $b(j)$  is the net cash flow.

Then, the PBP is the time period  $\tau$  resulting from the following condition:

$$NPV(\tau-1) < 0 \quad \text{and} \quad NPV(\tau) \geq 0$$

This discounted PBP was originally formulated for the classical cash flow pattern of an investment project with one change of sign, characterized by one or more negative cash flows followed by a sequence of positive ones. The definition does not ensure that, for any longer period of time, the project NPV also remains non-negative. In light of this, the PBP, denoted by  $\tau$ , can now be re-defined in the following fashion:

- a. If  $NPV(n) = NPV[v(z+1)] < 0$  then  $\tau = n+1$
- b. If  $NPV(n) = NPV[v(z+1)] \geq 0$ , then  $\tau$  results from the requirement:  
$$NPV(\tau-1) < 0 \text{ and } NPV(K) \geq 0, \text{ for } k = \tau, \tau+1, \dots, n$$

Note that the modified definition of the PBP implies that a prior calculation of the project's NPV is required, which automatically ensures full compatibility of the PBP criterion with the NPV.

Advantages of the payback period include the following:

1. Simplicity
2. It indicates how long the company's money is at risk and how soon it is recovered
3. Under certain conditions, the payback period closely approximates the rate of return on capital invested
4. It may be the most significant measure of the project worth in circumstances where instability, uncertainty, and technological changes make it difficult to forecast flows from a project beyond the immediately succeeding year.

Limitations of the payback period method include the following

1. It doesn't measure the project profitability
2. It doesn't measure the investment worth
3. It doesn't reflect the amount of money invested
4. Expected service life and salvage value are ignored
5. Deterioration and obsolescence are ignored

#### **2.4.4 The Annual Cost Minimization Method**

The Annual Cost Minimization (ACM) method can be defined as finding the annual equivalent of all the costs associated with an alternative and selecting the alternative that has the minimum annual cost.

The conventional presentation for the ACM method is to find the annual equivalent of the associated costs for that alternative. That can be found by first calculating the present worth or the net present value of all the associated costs and then multiplying it by the factor (A/P, i, n) that is called the annual-payment-series capital-recovery factor. This annual equivalent (AE) can be formulated as [Thuesen, 1993]:

$$AE(i) = PW(i) * (A/P, i, n) \quad (42)$$

The net present worth (PW) can be found by using the following formula [Thuesen, 1993]:

$$PW(i) = \sum_{t=0}^n \frac{F_t}{(1+i)^t} \quad (43)$$

Where:  $F_t$  is the future cost at year  $t$

The decision criterion for the ACM method is to Select the alternative that has the minimum annual cost.

In this method, the annual cost is normally calculated for each alternative. The alternative that has the minimum annual cost is considered to be valuable to present to management. The way to calculate the annual cost and the variables that are included in this calculation differs from one model to another. Following is a summary of the available models that consider the annual cost minimization method as replacement decision criteria.

#### **a. Classical Replacement Model**

The classical replacement model was presented by Hesse and Woolsey in the journal *Applied Management Science*. It compares the average cost per period for continuous individual item replacement upon failure with expected costs per period for total group replacement after n periods of individual item replacement [Reid, 1986]. This model assumes that replacement of an unfailed item with a new one is cost effective only if replacement costs are higher after failure has occurred, and that a newly installed item has a reduced probability of failure. The two inputs required for this model are an item's failure rate probability distribution and the unit costs for both individual and group replacement.

#### **b. Reassignment Model**

The model has been designed to assist in decision making regarding the manner in which particular equipment is assigned to field applications. The model can be used to identify pieces of equipment that are candidates for retirement or replacement when they are no longer cost effective in any available application for a particular contractor. This is achieved by combining

the tangible costs of continued ownership and operation with the consequential costs arising from age and deteriorating mechanical performance. This is done in the following form [Vorster, 1987]:

$$EC_{Ma} = \frac{(CO_{Ma} + CP_{Ma})}{PI_{Ma}} + FCS_{Ma} \quad (44)$$

Where  $EC_{Ma}$  = the effective cost of working machine type M in assignment a;

$CO_{Ma}$  = the tangible costs of continued ownership for machine M in assignment a;

$CP_{Ma}$  = the tangible costs of continued operation for machine M in assignment a;

$PI_{Ma}$  = the relative productivity index for machine M in assignment a;

$FCS_{Ma}$  = the failure cost surcharge for machine M in assignment a.

The relative productivity index  $PI_{Ma}$  is introduced in order to compensate for the fact that the productivity of machines of essentially similar type but different ages vary from application to application due to technological development. The index is presented in the form of a relative productivity matrix, which is obtained by assessing the productivity of each machine in each application. An example of a relative productivity matrix is given in figure 2.8.

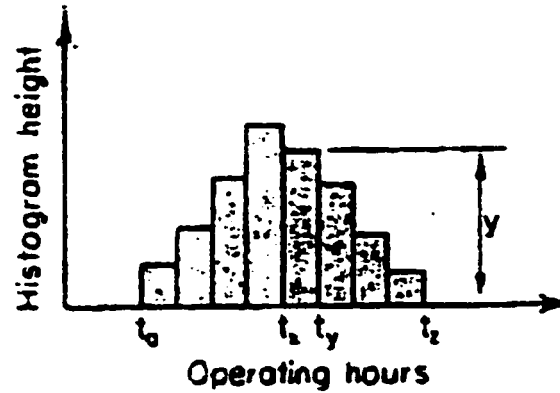


Figure 2.8 Relative Productivity Matrix

Determination of the future cost surcharge ( $FCS_{Ma}$ ) necessitates the use of the failure cost profile that was discussed in Section 2.3.8 together with the two simple measures for the mechanical performance of a particular machine. If it is once again assumed that costs are aggregated on an hourly basis, these may be expressed as follows:

$$H = D/V \quad (45)$$

$$G = (V \times 100) / W \quad (46)$$

Where  $H$  = average duration of an unscheduled failure;  $D$  = number of hours the machine was broken down in a particular period;  $V$  = number of unscheduled failures experienced by the machine in a particular period;  $G$  = number of unscheduled failures experienced by the machine for 100 working hours;  $W$  = number of hours worked by the machine in a particular period.

Given the above, the failure cost surcharge in SR/100 working hours can be calculated from the area under the failure cost profile as follows:

$$FCS_{Ma} = G_M \times R_M \times \sum_{Hr=0}^{Hr=Hm} FCP_{Ma} = G_M \times R_M \times \sum_{Hr=0}^{Hr=Hm} f(FC_{Ma}, Hs) \quad (47)$$

Where  $G_M$  = average number of unscheduled failures experienced by the particular machine per 100 working hours;  $H_M$  = average duration of the unscheduled failures experienced by the particular machine;  $R_M$  = standard owning and operating cost ratio for a given machine type used when defining the vertical scale of the failure cost profile.

### c. Comparative Annual Cost Method

The comparative annual cost method or CAC method has been suggested by Foster and Norton. It recognizes three major components of replacement cost: capital, operating, and deterioration and obsolescence (D&O) costs. Capital costs refer to costs associated with the use of money that is fundamental to the time value of money concept. D&O reflects annual equipment depreciation and increased operating costs due to obsolescence. Physical deterioration results in increased power and maintenance requirements, increased idle time and spoilage, and decreased safety and efficiency. Obsolescence costs occur because of better equipment design or a new technique that is available but not utilized. The equation for the comparative annual costs is as follows:

$$CAC = (P-S) (crf, i \%, n) + Si + D + G(GUS, i \%, n) \quad (48)$$

Where CAC = comparative annual cost; P = purchase price or present value;

S = salvage value; (crf, i %, n) = capital recovery factor

=  $I(1+I)^n / [(1+I)^n - 1]$ ; I = interest rate per year; n = expected service life in years; D = net annual operating cost;

G = D&C gradient; (GUS, i %, n) = discrete arithmetic gradient conversion factor.

Assuming that the cash flow is continuous and defining  $r$  as the annual rate of interest compounded continuously, one has the following:

$$(crf, i\%, n) = r e^{rn} (e^{rn} - 1)$$

$$(GUS, i\%, n) = 1 / (e^r - 1) - n / (e^{rn} - 1)$$

Substituting in equation (48) above and taking the derivation to get  $G$  will provide the final, following equation:

$$CAC = (P-S) [r e^{rn} (e^{rn} - 1) + r^2 e^{rn} \{ 1 / (e^r - 1) - n / (e^{rn} - 1) \} / \{ 1 - e^{rn} (1 - nr) \}] + Si + D = (P-S) (ACPG, r\%, n) + Si + D \quad (49)$$

Where ACPG is an acronym for annual cost plus gradient, which represents the terms between the square brackets of equation (49).

Following are the assumptions made for the CAC method:

- i. The D&O gradient  $G$  increases as an arithmetic progression. Most equipment has an increasing operating cost each year.
- ii. The effect of technological changes on demand for new alternatives is ignored
- iii. The salvage value is constant
- iv. The expected service life is constant
- v. Difference in service life of all alternatives is ignore



#### **d. Uniform Annual Cost Method**

This method requires that uniform annual costs be already expressed in the required form if they are assumed to be constant. Hence, only the current market value of the existing equipment, the purchase price of the new alternatives, and the salvage values of all alternatives must be converted to their uniform annual equivalents. The conversion is done with the use of compound interest factors. The relevant factor is the capital recovery factor (crf) which is given by [Beenhakker, 1975]:

$$Crf = I (1+I)^n / [(1+I)^n - 1] \quad (50)$$

Where: I = interest rate; N = expected service life

To find the annual equipment salvage value, we find the equivalent of the salvage value at the point in time where the equipment would be purchased, which is at the beginning of the first year. That is done with the single payment worth factor (sppwf), which is given by:

$$Sppwf = 1 / (1+I)^n \quad (51)$$

Comparing this with the other alternatives will facilitate the decision. The difference between the uniform annual cost method and the present worth method is that the present worth method converts all the cash flow to the time of the first year.

#### **e. Compromise Method**

This method was first proposed by Mayer. It avoids much of the inaccuracy of the payback method, and the computations are easier and less time consuming than those of the uniform annual cost method. The compromised method is based upon approximating the components of

equipment costs (depreciation, interest, and operating expenses) by averages over the expected service life of the equipment [Beenhakker, 1975].

### **2.4.5 The Total Cost Minimization Method**

The Total Cost Minimization (TCM) method can be defined as the sum of all the costs for equipment over the investment period and then selecting the alternative that has the minimum total cost.

The conventional presentation for the TCM method is to find the sum of the present worth of all the future and present costs for an alternative. This sum represents the total cost. The net present worth (PW) can be found by using the following formula [Thuesen, 1993]:

$$PW(i) = \sum_{t=0}^n \frac{F_t}{(1+i)^t} \quad (52)$$

Where:  $F_t$  is the future cost at year  $t$

The decision criteria for the TCM method is to find the present worth of the present and future costs for each alternative and select the one that has the minimum total cost.

The overall cost is computed here for all the cost elements, and the alternative that has the minimum total cost is selected. Following are some of the models that use this replacement decision criteria.

#### **a. Alchian's Model**

Alchian (1952) recognized that benefits or revenue streams generated by a unit of equipment are not always easy to estimate. He proposed total cost minimization. Cost components suggested

for consideration in his model include the present worth of maintenance, repair, and other operating costs; the present worth of depreciating resale values for the equipment; and the present worth of the acquisition of cost of future machines [Jaafari & Mateffy, 1993].

## b. Infinite Horizon Model

Morris (1976) presented a general replacement model that aims at estimating the total cost for existing equipment and replacements on a current dollar basis [Jaafari & Mateffy, 1993]:

$$TC(N_1, N_2, \dots, N_k) = I_0 + \sum_{j=1}^{N_1} \left[ \frac{O_{0j}}{(1+i)^{**j}} \right] - \frac{S_{0n1}}{(1+i)^{**n1}} + \frac{I_{n1}}{(1+i)^{**n1}} \\ + \sum_{j=1}^{N_2} \left[ \frac{O_{n1j}}{(1+i)^{**n1+j}} \right] - \frac{S_{n1n2}}{(1+i)^{**n1+n2}} + \frac{I_{n2}}{(1+i)^{**n1+n2}} + \dots \quad (53)$$

Where  $TC(N_1, \dots, N_k)$  = total cost of a series of machines that are replaced at intervals of  $N$  years;  $I_t$  = initial investment in a machine purchased at the end of period  $t$ ;  $O_{tj}$  = operating and maintenance costs for the  $j$ th year of use for a machine purchased at the end of period  $t$ ; and  $S_{tj}$  = salvage value at the end of the  $j$ th year of use for a machine purchased at the end of period  $t$ .

This procedure requires a vast array of input data for cost functions, particularly if the chain of replacements are dissimilar and when the planning horizon incorporates a significant number of replacement cycles.

### c. Geometric Gradient-To-Infinite-Horizon Model

Collier and Jacques (1984) developed the following geometric gradient-to-infinite-horizon model [Jaafari & Mateffy, 1993]:

$$GTC(N,L) = PTD(N) + \frac{PTC(L)}{(1+i)^{**N}} \quad (54)$$

Where  $GTC(N,L)$  = the granted total cost;  $PTD(N)$  = the discounted total cost of the equipment's initial cost, salvage value, maintenance, and insurance;  $PTC(L)$  = the total cost of an infinite chain of replacements;  $N$  = the equipment residual life; and  $L$  = the equipment design or life span.

Although this model is realistic and flexible to apply, it has some shortcomings. For example, the interest charges on the investment have been omitted.

### a. ERA Model

The equipment replacement ERA model was developed by Jaafari & Mateffy in 1993. For the most part it resembles the model suggested by Collier and Jacques (1984). The model is represented by the following equation:

$$TPC(N,L) = PCE(N) + \frac{PCR(L)}{(1+i)^{**N}} \quad (55)$$

Where  $PCE(N) = \sum_{k=1}^{k=12} PVE_k(N)$ ;  $PCR(L) = \sum_{k=1}^{k=12} PVR_k(L)$ ;  $TPC(N,L)$  = the total present cost;  $N$  = the remaining life of existing equipment;  $L$  = the life cycle of the equipment;  $PCE(N)$  = sum of the present costs of the existing equipment  $PVE_1, PVE_2, \dots$ ;  $PCR(L)$  = sum of the present costs of the replacement equipment  $PVR_1, PVR_2, \dots$ .

Jaafari & Mateffy developed and used the following two key factors to calculate all the above cost functions:

$$(gf) = \left[ \frac{(1+i)^{**n} - 1}{i(1+i)^{**n}} \right] \quad (56)$$

and

$$(rf) = \frac{1}{1+Re} \left[ \frac{(1+We)^{**NC} - 1}{We(1+We)^{**NC}} \right] \quad (57)$$

Where gf = the gradient factor; rf = the replacement factor.

#### 2.4.6 The Economic Life Method

The Economic Life (EL) is the optimum replacement period or the minimum cost life where the total annual revenues equivalent will be higher than the total annual expenses equivalent.

Generally, the equipment manufacturer estimates the economic life for the equipment by providing the equipment performance curve. However, this duration will be affected by the equipment use and may vary drastically based on how good is the maintenance program and how good is the equipment utilization.

There are many developed models that compute the optimal year of replacing construction equipment. Jardine has developed some models that estimate the replacement age based on the main controlling factors. None of these models will be discussed here. Following are some models that compute the optimal replacement age.

### a. Taylor's Model

Taylor (1923) offered the following equation for determination of the economic life of a piece of equipment [Jaafari & Mateffy, 1993]:

$$X_n = \frac{O_n + I_n + D_n}{Y_n} \quad (58)$$

Where  $X_n$  = average unit cost of production over  $n$  years of service;  $O_n$  = commutative operating expenses for  $n$  years, including repairs, operator, fuel, overhead costs;  $I_n$  = commutative interest cost for  $n$  years;  $D_n$  = depreciating cost over  $n$  years, which is the difference between the acquisition cost of the new machine and its estimated salvage value after  $n$  years of service; and  $Y_n$  = commutative number of units of output for  $n$  years of production.

Taylor's model is easy to apply using spreadsheet software on desktop computers. Its serious omission is its disregard for technological advancements in future equipment.

### b. Incremental Cost Model

This model computes the after mentioned optimal year with the help of the following expression [Beenhakker, 1975]:

$$C(n_0) = \sum_{t=1}^{t=n_0} [s(t) + D_O(t)] + (T - n_0)(P - S + E) / n \quad 0 \leq n_0 \leq T \quad (59)$$

Where  $C$  = cost of maintaining capacity during the entire planning horizon (function of  $n_0$ );  $n_0$  = the number of additional years the defender is kept;  $n$  = expected service life of the challenger (in years);  $T$  = planning horizon in years;  $s(t)$  = decline in the salvage value of the defender in year  $t$ ;  $D_O(t)$  = defender's cost of operation in year  $t$ ;  $P$  =

challenger's purchasing price;  $S$  = salvage value of the challenger;  $E$  = total costs of challenger's operation over its service life of  $n$  years.

The incremental cost method is based on the following assumptions:

1. The expression  $(T - n_0)(P - S + E)/n$  ignores the time value of money.
2. The choice of  $n_0$  has no influence on the purchasing price, salvage value, and expected service life of the challenger.
3. The effects of technological changes on demand for the challenger's output are ignored.
4. Differences in utilization rates of defender and challenger are ignored.
5. The service life of a single machine is treated in isolation from the service life of each machine in the chain of future replacements. In fact the above expression does not consider the possibility of two or more successive replacements during the planning horizon.

### c. Cost Flow Model

Preinreich has shown that it is incorrect to determine the optimal service of a single machine in isolation from the service life of each machine in the chain of future replacements extending as far into the future as a firm's profit horizon [Beenhakker, 1975]. He argues that a firm should maximize the present value of the costs of all such machines or maximize  $V$  where:

$$V = \sum_{k=0}^{\infty} e^{-rk_n} \left\{ \int_0^n [R(t) - D(t)] e^{-rt} dt + S(n) e^{-rn} - P \right\} \quad (60)$$

Where  $r$  = annual rate of interest, compounded continuously;  $e$  = base of the natural logarithms;  $R(t)$  = machine's revenue at a time  $t$ ;  $D(t)$  = machine's operating costs at a time  $t$ ;  $n$  = service life in years;  $S(n)$  = salvage value as a function of  $n$ ;  $P$  = purchasing price of each new machine in the replacement chain.

This approach, which is called the Cash Flow Method, assumes that equipment obsolescence and deterioration affect only operating cost. The model is concerned with replacement of machines with units of identical type.

The above expression is simplified by making the following assumptions:

1. The service lives of successive units in the replacement chain are equal;  
 $n_1 = n_2 = \dots = n_{k+1} = n$ .
2. The utilization rate of the defender and future replacement equipment is the same;  
 $u_0 = u_1 = u_2 = \dots = u_{k+1} = \text{constant}$ .
3. The purchase price of future equipment remains constant;  $P_1 = P_2 = \dots = P_{k+1} = P$ .
4. The salvage values of the defender and all the future replacement machines are constant and amount to  $S$  and  $S$ , respectively.

The simplified equations are as follows:

$$n^* = \sqrt{2(P - S) / (\alpha - \beta)} \quad (61)$$

$$d'^* = \Delta - \beta n_o^* - \beta/r + \sqrt{2(P - S) / (\alpha - \beta)} + rS \quad (62)$$

$$n_o^* = [ \Delta - \Delta_o + \sqrt{2(P - S) / (\alpha - \beta)} + r(S - S_o) ] / (\alpha_o + \beta) \quad (63)$$



Where  $n_o^*$  = the optimal value of the number of additional years the defender should be kept;  $n^*$  = the optimal value of the service life of the challenger;  $d'^*$  = the discounted annual cost of installing and maintaining new equipment and following an optimal replacement policy forever after;  $\Delta_o$  = the present ( $t=0$ ) operating expense of the defender;  $\Delta$  = the first-year operating expense of the best currently available model of new equipment which would be installed if the defender were discarded at  $n = 0$ ;  $\beta$  = the rate of technological change, measured by the amount that the first-year operating cost of new equipment decreases each year as a consequence of model improvements;  $\alpha_o$  = the rate at which the operating expenses of the defender increase with age; it measures the rate at which economic deterioration occurs;  $\alpha$  = the rate at which the operating expenses of future replacements are expected to increase with age.

#### **d. Dynamic Programming Model**

The dynamic programming approach to the formulation of a replacement policy has been developed by Bellman. The function  $f(t)$  is defined as the present discounted value of all capital and operating costs associated with a facility or machine of age  $t$  years employing an optimal replacement policy, where  $t = 0, 1, 2, 3, \dots$ . At anytime  $t$ , one is faced with two alternatives, i.e. keep the defender for another year, that is, until  $t+1$ , or purchase a new machine.  $F(t)$  satisfies the following relation if the defender is kept [Beenhakker, 1975]:

$$f(t) = D(t) + f(t+1) / (1+I) \quad (64)$$

Where  $f(t) = f(t)$  in case one decides to keep the defender at a time  $t$ ;  $D(t)$  = defender's operating cost at time  $t$ ;  $I$  = interest rate per year.

The cost associated with the action of keeping the defender at time  $t$  is the defender's operating cost for an additional year plus the discounted future cost employing an optimal policy. If a new machine is purchased at  $t$ , then

$$f(t) = P - S + D(0) + f(1) / (1+I) \quad (65)$$

Where  $f(t) = f(t)$  in case one decides to replace the defender at time  $t$ ;  $P$  = purchasing price of the challenger;  $S$  = salvage value of the challenger;  $D(0)$  = first year operating expenses of the challenger.

The two expressions above are used to define a functional equation for  $f(t)$ :

$$f(t) = \min \text{ of } \begin{array}{l} \text{a. } f(t) = D(t) + f(t+1) / (1+I) \\ \text{b. } f(t) = P - S + D(0) + f(1) / (1+I) \end{array}$$

### **e. Rent Replacement Model**

Rent models are used to assess the economic life of an industrial plant. A constant rent (or payment) is estimated by equating the NPV (Net Present Value) of all costs (or benefits) with the NPV of hypothetical rents made at constant intervals (annually).

The optimal replacement age is then chosen such that the rent is minimized or the payment is maximized. The term 'rent model' was first used in 1987 by Christer and Waller though this type of model was referred to by Churchman et al. and was used to solve replacement problems by Russell [Kobbacy, 1994].

Rent models can vary significantly according to the need of analyzing a specific problem. The simplest one-cycle rent replacement model assumes that the equipment under consideration is new and that the annual operating cost and rent are incurred at the half-year mark.

Given that  $r$  is the discounted factor for year  $k$ , then

$$r_k = \frac{(100 + jk)}{(100 + ik)} \quad (66)$$

Where  $j_k$  and  $i_k$  are the inflation rate and interest rate for year  $k$ , respectively.

The discount factor over  $n$  years to the end of the year,  $R_n$ , is given by

$$R_n = \prod_{k=1}^n r_k \quad (67)$$

Where the discount factor to the midpoint of year  $n$ ,  $H_n$ , is given by

$$H_n = \prod_{k=1}^{n-1} r_k \sqrt{rn} \quad (68)$$

By equating the total discounted cost with the total discounted rent, one can calculate the rent from the following:

$$\text{Rent} = \left[ \sum_{k=1}^m Q_k \times H_k + (C - S_m) \times R_m \right] / \sum_{k=1}^m H_k \quad (69)$$

Where  $m$  = replacement period of equipment in years;  $Q_k$  = operating cost of equipment in year  $k$ ;  $C$  = capital cost of replacement equipment;  $S_m$  = resale value of  $m$  years old equipment.

This basic model can be modified to enable the examination of the effects of important parameters on replacement age such as taxation. The two-cycle rent model is a variation that can help in deciding the optimal replacement age of a currently owned piece of equipment, i.e. used equipment and also the optimal replacement age of its replacement. This is achieved by equating the total discounted cost over the lives of the two pieces of equipment with the total discounted rent over the same period. Inflation and interest rates, and hence the discounted factor, are

uncontrolled variables to the study of the replacement of capital equipment. Simulation has been used in some literature to study the sensitivity of these factors.

#### **2.4.7 Profitability Index (PI) Method**

The profitability index (PI) is the ratio of the net cash flow to the amount of money invested to buy the equipment. This is used normally for ranking alternatives. The following formula is normally used:

$$PI = \frac{NPV(Net\_Cash\_Flow)}{PV(Investment)} + 1 \quad (70)$$

This indicator is often used as a budget-ranking tool for replacement alternatives.

## **CHAPTER 3**

### **RESEARCH METHODOLOGY**

This chapter presents the steps that were conducted to accomplish the research objectives. These steps are summarized in Figure 3.1 and described briefly below.

As mentioned before the three research objectives are 1) investigating and identifying the current equipment replacement methods, 2) studying the factors that are considered in the replacement decision, and 3) evaluating the existing equipment replacement policy of construction contractors in the Eastern Province of Saudi Arabia.

To achieve the research objectives, questionnaires were distributed to collect the required data. The following paragraphs present the methodology that was used to achieve the objectives.

#### **3.1 REQUIRED DATA**

An extensive literature review was conducted. This review covers various equipment replacement methodologies and theories, construction equipment economics, and other equipment management aspects. However, it is necessary to become familiar with business and field practices and principles regarding equipment replacement policies for local construction companies. As a result of the literature review, the following data found to be required to evaluate the current equipment replacement policies used by local construction firms:

1. Description of the current equipment replacement procedure:
  - When was it developed?
  - What are the organizational divisions that are involved in the analysis?

- How often does the firm conduct an equipment replacement analysis?
  - What are the contents of the equipment replacement procedure?
2. Factors that control the replacement decision:
    - What are the factors that influence the replacement decision?
    - How does the firm measure the effect of each factor on the replacement decision?
  3. Financial equipment replacement method:
    - What are the financial methods that are used to evaluate the equipment replacement proposals?
    - How does the firm search for the replacement alternatives?
    - What are the advantages and disadvantages of the currently used replacement method?
  4. Equipment economy:
    - What kind of financing does the firm use to acquire equipment?
    - What depreciation accounting method does the firm use for construction equipment?
    - How does the firm determine the economic life of its construction equipment?
  5. What equipment cost records does the firm maintain?
  6. When does the firm dispose of its construction equipment?
  7. How does the firm dispose of its construction equipment?
  8. What are the strengths of the current equipment replacement model?
  9. What are the weaknesses of the current equipment replacement model?

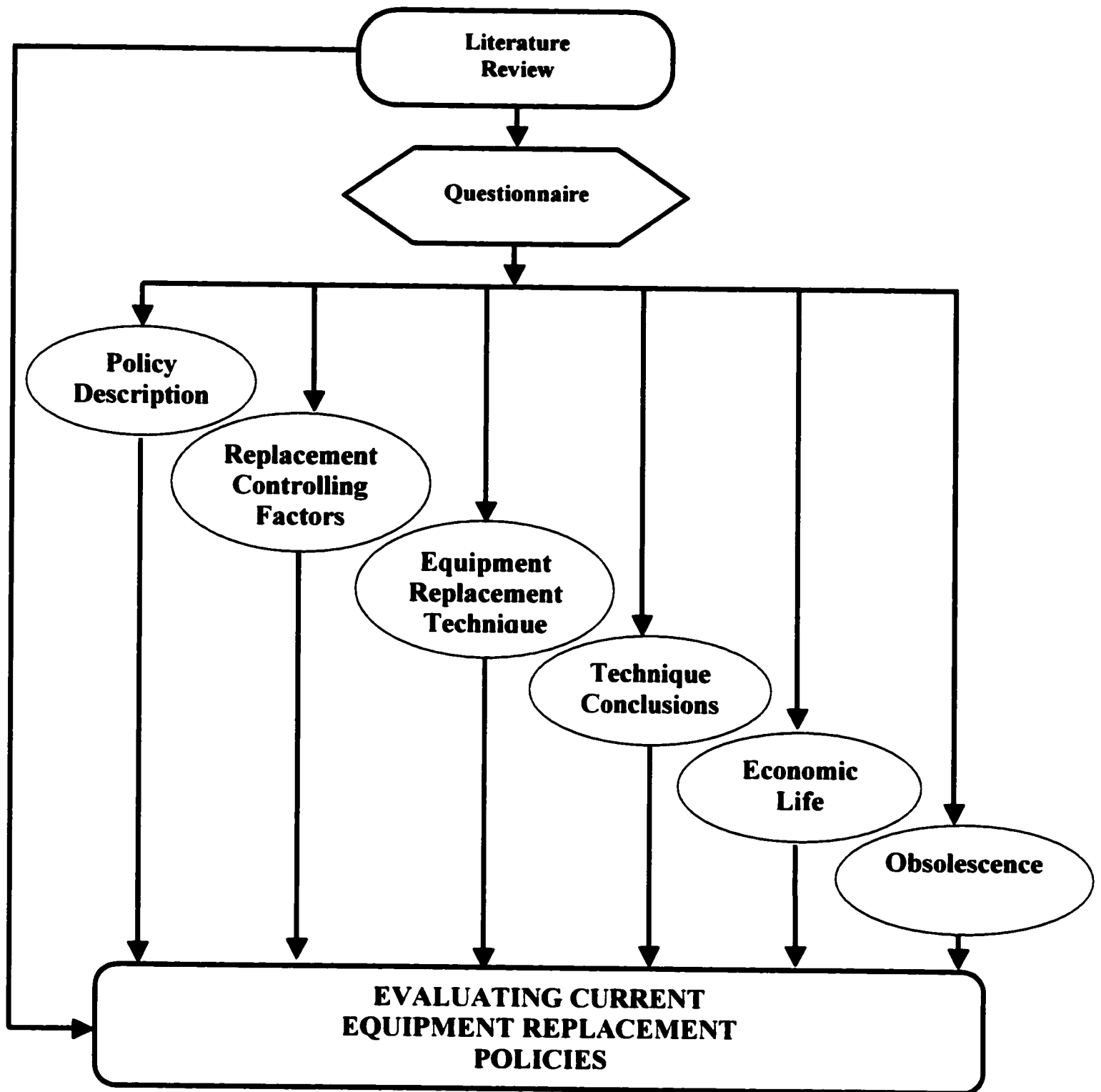


Figure 3.1: Research Method

### **3.2 DATA COLLECTION**

The required data was collected from construction contractors in the Eastern Province of Saudi Arabia. A structured questionnaire was used to collect the necessary data.

The data was divided into six groups. The first group is a description of the current replacement policy used by each firm in evaluating its equipment and deciding on the best replacement time and alternative. The second group is an identification of the financial techniques used to evaluate the replacement proposals. The third group is a study of the factors that have to be considered and assessed in the replacement process. The fourth group is the detail of the replacement technique that is used to evaluate the equipment replacement proposals and the conclusions that used to make the replacement decision. The last two groups are the miscellaneous information that are used during the replacement process such as equipment records and maintenance.

The existing policies are evaluated based on the engineering science and literature review to develop conclusions to evaluate and improve the currently used equipment replacement policies.

### **3.3 POPULATION AND SAMPLING**

In this study, the population was selected from a trade directory published by the Ministry of Housing and Public Works. The ministry classifies contractors into different fields and activities as shown in Table 3.1.

The Ministry of Housing and Public Work also classifies each field into five grades based on the largest project volume to be undertaken by a classified contractor for each grade in each field in millions of Saudi Riyals as shown in Table 3.2.

The contractors listed in the top three grades (classified according to the turnover of the companies by the ministry) and which are located in the Eastern Province of Saudi Arabia



have been selected because they undertake works of a considerable cost, which necessitates the employment of heavy construction equipment. Also, the types of work listed use construction equipment on a large scale.

Seventy-four contractors were found to meet these requirements. These form the population of the study. Since the population is small, approaching all the contractors was attempted.

## **DAMS**

- Earth Dams
- Concrete Dams

## **WELL DRILLING**

- Surface Wells

## **MAINTENANCE & OPERATION**

Building Maintenance	Operation of Electrical, Mechanical Instl.
Road Maintenance	Maintenance of Electrical, Mechanical Instl.
Maintenance & Operation of W/S System	Maintenance of Electrical Instl.
Operation of W/S System	Operation of Electrical Instl.
Maintenance of W/S System	Maintenance & Operation of Electrical Instl.
Maintenance & Operation of Water System	Operation of Mechanical Instl.
Maintenance & Operation of Electrical, Mechanical Instl.	Maintenance of Mechanical Instl.

## **GENERAL MAINTENANCE**

### **BUILDINGS**

- Public Buildings
- Housing
- Commercial Buildings
- Educational Buildings
- Recreational Buildings
- Medical Facilities
- Airport Buildings
- Prefabricated Buildings

### **ROADS**

- Highways
- Streets
- Bridges
- Tunnels
- Railroads
- Airports
- Earth Moving

### **WATER & SEWAGE SYSTEMS**

- Water Networks
- Sewage Networks
- Storm Water Drainage
- Water Treatment Plants
- Sewage Treatment Plants
- Agricultural Development

### **ELECTRICAL WORKS**

- Power Generation
- Power Trans. & Dist.
- Lighting
- Communication Net.
- Electronic Instl.

### **MECHANICAL WORKS**

- A/C & Refrigeration
- W & S Treatment Plants
- Pump Stn's & Treat. Plants

### **INDUSTRIAL WORKS**

- Industrial Plants
- Refin. & Petr-Chm. Plts
- Oil & Gas Pipelines
- Water Desalination

### **MARINE WORKS**

- Harbors
- Shipyards
- Dredging
- Underwater Lines & Tunnels
- Sea Bridges

Table 3.1 Fields and Activities of Classifications

GRADE ACTIVITIES	FIRST	SECOND	THIRD	FOURTH	FIFTH
Buildings	Over 200	200	50	15	5
Roads	Over 300	300	100	30	10
Water & Sewage	Over 300	300	100	30	10
Electrical Works	Over 200	200	50	15	5
Mechanical Works	Over 200	200	50	15	5
Industrial Works	Over 300	300	100	30	10
Marine Works	Over 300	300	100	30	10
Dams	Over 100	100	50	15	5
Maintenance & Operations	Over 100	100	30	10	3

**Table 3.2      Financial Limits in Millions of Saudi Riyals for Classification Grades-Saudi Contractors**

The questionnaire was mailed to all the 74 contractors. Then it was faxed again to all the contractors who did not respond in order to improve the response rate. Twenty-one contractors responded and mailed or faxed back the questionnaire. Four companies said that they are no longer on the construction business.

These 4 companies were, hence, removed from the population, reducing the population size to 70. Therefore, a total of 21 filled up questionnaires were received back which were used for the research.

The response of 21 participants comprises 30% of the total population.

### **3.4 DATA ANALYSIS**

The gathered data from the survey was subjected to statistical analysis to interpret the available data properly and meaningfully, and to present the results in a form useful to draw conclusions and come up with recommendations to contractors, to modify or improve their existing equipment policies. The study and analysis is presented in a manner such that conclusions and inference could be drawn.

The collected data was analyzed by using the SAS statistics package. The data was analyzed such that it will shed light on the scenario of equipment management in the Eastern Province of Saudi Arabia. Some of the statistical techniques that were applied are; basic descriptive statistics, cross tabulation, and frequency tables.

## **CHAPTER 4**

### **RESULTS ANALYSIS**

#### **4.1 INTRODUCTION**

This chapter utilizes the collected data to present the most widely equipment replacement practices and formulate an equipment replacement policy that can be used to manage construction equipment utilization and need.

The obtained data were coded and analyzed using the Statistical Analysis Software (SAS). The SAS software produces frequency and percentage tables, correlation, and cross-tabulation for the data which was used to analyze the response of the contractors to the related questions. The participants gave more than one response to some of the questions since these questions can have more than one probable answer. Hence the total number of responses to some questions is more than the number of participants.

Characteristics of the participants are detailed in the second section. It covers the type of construction they are doing, the related grade given by the Ministry of Housing and Public Work, their experience, and their annual work volume of the contractors.

Construction equipment acquisition methods are discussed in the third section. The acquisition is usually through owning, leasing, and renting the equipment. In addition to that, the values of owned equipment for the construction contractors are covered in this section.

The equipment replacement policy analysis is done in the fourth section. This covers the organizational rules for the replacement policy, the replacement time and need, the financial

methods that are commonly used to do the replacement analysis, and the factors that affect or control these evaluation methods.

Other issues like; equipment financing, equipment economics, equipment cost records, maintenance, and disposal are also discussed in this chapter.

## **4.2 CHARACTERISTICS OF THE PARTICIPANTS**

The following sections describe the characteristics of the contractors that participate in the survey. These characteristics include the type of work and grade according to the Ministry of Housing and Public Work classification, the annual work volume, and the experience.

### **4.2.1 Type of Work**

It has been found that the participants perform diverse jobs. Due to the industrial environment of the Eastern Province, the following types of work were selected as major fields that are normally undertaken by the contractors; Buildings (including commercial and residential), Roads (including Highways and inter-city roads), Industrial, Electrical, and Mechanical works. The distribution of the 21 participants according to the type of work performed is shown in Table 4.1. The number of contractors, in the frequency table according to the type of work performed, is more than 21 as some of the contractors are involved in more than one type of construction. As seen from Table 4.1, the majority of the participants are involved in building construction work. This may be due to the grew up and expansion of the cities due to the increasing demand for more and better housing. The increasing demand is due to the increasing population of the country and the continuous expansion on the industrial constructions and projects. Other types of

construction works like, industrial, electrical, and mechanical have equal involvement chances of about 30% from the participants. This may be due to the industrial nature of the eastern province and the continuous increase in the number of industrial projects undertaken to make the country self-reliant on industry.

In addition, one third of the participants are doing road construction work. This may be due to the nature and spread borders of the country and the efforts made to connect the cities with new highways that shorten the distance between cities and make travel more easy.

<b>Construction Type</b>	<b>Frequency</b>	<b>Percent</b>
<b>1. Building</b>	12	57.14
<b>2. Roads</b>	7	33.33
<b>3. Industrial</b>	6	28.57
<b>4. Electrical</b>	8	38.10
<b>5. Mechanical</b>	5	23.81

Table 4.1      Type of Construction

#### **4.2.2 Annual Work Volumes**

It is found that the annual work volume of the participants range between SR 8 million to SR 412 million. The participants are divided into three grades based on the annual work volume. This classification is in accordance to the grading done by the Ministry of Housing and Public Work. The distribution of the participants according to their grade is given in Table 4.2. Participants who did not indicate their annual work volume are not given any grade. The contractors who have an annual work volume of SR 1 to 100 million are classified as Grade III. The contractors whose annual work volume range between SR 100 and SR 200 millions are classified ass Grade II, and the contractors whose annual work volume is above SR 200 million are classified as Grade I.

As seen from Table 4.2, the majority of the participants fall in Grade III. Also it was found that the annual work volume of Grade I contractors is the highest and ranging between SR300 and 412 million. The average annual work volume of the participants is SR 80.35 million. It is noted that 14 participants have an annual work volume below the average and 6 participants have an annual work volume above the average.

<b>Annual Work Volume</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
<b>0 (Value not indicated)</b>	1	4.76	1	4.76
<b>Grade 3: 1-100 Million SR</b>	14	66.67	15	71.43
<b>Grade 2: 101-200 Million SR</b>	3	14.29	18	85.71
<b>Grade 1: Above 200 Million SR</b>	3	14.29	21	100.00

Table 4.2 Annual Work Volume

These details reflect the reality of the industrial revolution in Saudi and how much money is being invested in building the backbone and the supportive construction facilities.

#### 4.2.3 Experience

Table 4.3 shows the distribution of the participants according to their experience. The results indicate that all the participants have been in operation for many years, ranging between 15 and 50 years with an average age of 26 years. Most of the participants are in the age of 20-30 years. It can be seen from Table 4.3 that almost all the participants are well-established contractors. This means that the participants have a set of fairly well established procedures of work and equipment management system. It is also indication for better and improved credibility of the contractors. This good range of experience is an indication for much more improved and reliable source of information that can be used to conduct studies and analysis to improve the existing



systems that are being used by the contractors and help other firms to improve their systems too. About 8 contractors are older than the average age and 13 contractors have an age less than the average age.

<b>Years of Experience</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
15 - 20 Years	4	19.05	4	19.05
21 - 25 Years	9	42.86	13	61.90
26 - 30 Years	5	23.81	18	85.71
31 - 35 Years	1	4.76	19	90.48
Above 35 Years	2	9.52	21	100.00

**Table 4.3 Ages of Participants**

The cross tabulation of the contractors age with the grade shows that a majority of the participants from Grade III are in the age of 21-25 years whereas the majority of Grade II contractors are in the age group of 26-30 years. The majority of Grade I contractors have a greater experience than the participants from other grades. When a contractor starts business, he starts being a small contractor. As the company grows in experience and executes more projects, it's profit increases that encourage the company to increase its size in order to be able to take more projects.

### **4.3 EQUIPMENT ACQUISITION METHOD**

Contractors are concerned with a decision as to whether to purchase, rent, or lease equipment. Under certain conditions it is financially advantageous to purchase, whereas under other conditions it is more economical and satisfactory to rent the equipment. The method that is

selected is normally the one that will provide the use of the equipment at the lowest total cost and consistent with the usage and production that the contractor will make from the equipment.

#### **4.3.1 Equipment Ownership**

Owning the equipment could be through outright purchase or credit sale. Outright purchase is simply payment of the purchase price by the acquiring company to the supplier. A credit sale is a sale in which the acquiring company takes the ownership or title of the equipment immediately but the purchase price is paid in installments. These installments include the purchase price plus some financing charges to the supplier. In both methods the owner will be responsible for the equipment operation and maintenance. Normally the supplier give few months of warranty period to give the owner sometime to identify any manufacturing defects and to test the equipment efficiency and suitability to the job specified in the purchase order specifications.

It was found that the fleet value of the equipment owned by the participant's range between SR 72,000 and SR 250 million. The average equipment fleet value of the participants is SR 54.185 million. The majority of the participants have equipment fleet value ranging from SR 1 to 20 million. Nine participants did not indicate the value of their equipment fleet. Three participants have their equipment value above SR 40 million. These values are very high when compared to the rest of the participants. These range between SR 140 million to SR 250 million in value. Nine participants have an equipment fleet value below the average while three participants have a fleet value above the average.

<b>Equipment Fleet Value (Million SR)</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
0 (Value not indicated)	9	42.86	9	42.86
1 to 10	4	19.05	13	61.90
11 to 20	4	19.05	17	80.95
21 to 40	1	4.76	18	85.71
Above 40	3	14.29	21	100.00

**Table 4.4      Owned Equipment Fleet Value**

It was found that the contractors from grade I have fleet of the highest value. A majority of grade II participants have a fleet value between SR 10-35 million while the majority of the participants from grade III have a fleet value ranging between SR 1-10 million. This clearly shows the decreasing value of equipment fleets among the participants, according to their grades. The participants of higher grade generally have a fleet of greater value than a participant of a lower grade. All the contractors own some construction equipment. The ownership ranges between 30-100% of the fleet. The average ownership rate is 83.286%. This high rate indicates that most of the contractors like to own construction equipment. This tendency might be due to the shortage and less use of the other methods of getting the equipment, lease and rent, in Saudi. Also, this high ownership rate might be due to the difficulty of getting immediate replacement for the equipment in case of failure or getting the equipment even fixed at an acceptable period of time in case of failure without impacting the contractors project schedule or causing very high repair cost. This is due to the long lead-time of getting equipment or parts from the manufacture since most of the equipment is manufactured out side the kingdom.

Table 4.5 lists the commonly used types of equipment and the minimum, maximum, and average number of equipment for the participants. The table indicates that the contractors tend to own considerable number of small size equipment that will be enough to fulfill the demand and jobs

requirements. On the other hand, they tend to own few from the special type of equipment that have less usage. This is reasonable to ensure that the company will not invest an amount of money to buy equipment that is rarely used and could be easily rented with reasonable price when it is needed.

<b>Construction Equipment Type</b>	<b>Minimum Number</b>	<b>Maximum Number</b>	<b>Median</b>
Dozer	0	70	18.47
Loader	0	38	9.82
Welding Machine	0	334	47.35
Air Compressor	0	114	15.65
Generator	0	65	12.24
Dump Truck	0	136	18.89
Crane	0	72	10.59

**Table 4.5      Types of Construction Equipment**

#### **4.3.2 Equipment Lease**

The difference between leasing and purchasing is that the ownership of the equipment remains the property of the leasing company (the lessor) and the acquiring company (the lessee) never becomes the owner. The acquiring company (the lessee) only acquires the use of the equipment in return for payments or rentals.

The survey results indicated that the majority of the contractors are not leasing construction equipment. This is may be due to ambiguity of the leasing procedure and the unavailability of leasing companies in Saudi Arabia.

### **4.3.3 Equipment Rent**

The difference between renting and leasing of construction equipment is that leasing is along term rent. Renting is the use of equipment for short terms such as daily, weekly, or monthly periods. When equipment is rented the lessor provides the required repair and maintenance, whereas in leasing arrangement the repair and maintenance of the equipment is the lessee's responsibility.

The survey results indicated that every contractor rent some construction equipment. The average renting rate is 16% of the used equipment. The renting rate ranges between 1-70% of the equipment needed for construction.

## **4.4 EQUIPMENT REPLACEMENT POLICY**

The equipment replacement policy is the procedure or practice that is followed to monitor owned construction equipment performance, total cost, and the company need for additional construction equipment in order to come up with the best replacement decision that maximize the total profit and reduce the expenses and losses. It is a regular quantitative analysis that is required to control and balance the equipment need and usage. Companies might need the policy to replace inefficient equipment, inadequate equipment, or to add equipment to satisfy growing demand. A written policy or equipment replacement manual is desired because it is very important to make the replacement procedure clear, stipulated, and well documented. This helps to improve and modify the procedure whenever required. It also helps the company personnel to be familiar with the replacement procedure.

The results indicate that only 19% of the participants have written equipment replacement policy while the majority of the contractors do not have written policies. The frequency distribution according to the type of policy is presented in Table 4.6.

<b>Equipment Replacement Policy</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. No Written Policy Manual	17	80.95	17	80.95
2. Written Policy Manual	4	19.05	21	100.00

Table 4.6      Equipment Replacement Policy

It was found that two Grade III participants, one grade II participant, and one grade I participant have written equipment replacement policy. This means that 14% of grade III participants, 33% of grade II, and 33% of grade I participants have written equipment replacement policy. This indicates that most of the contractors do not have well documented replacement procedure. As per the discussion with some contractors, the equipment never gets replaced unless it reaches end of its life and new equipment are bought whenever management decide to buy. This low percentage of documented equipment replacement policy might be due to the way the contractors evaluate the existing equipment and the way they take their replacement decision. Most of the replacement decisions are taken based on the current need and experience in making decision without analytical data.

Two of the participants indicated that the replacement policy is section of the equipment management policy; one indicated that it is stand alone policy, and one did not respond to the question.

The replacement policy was developed just about five years ago for most of the participants who has written replacement policy and it was developed about 25 years ago for one of the

participants. This indicates that the policy was adopted recently and the contractors are still improving it periodically as shown in Table 4.7.

<b>Updating Frequency</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Monthly	1	25.00	1	25.00
2. Yearly	1	25.00	2	50.00
3. Every 5 Years	1	25.00	3	75.00
4. Job-Wise	1	25.00	4	100.00

**Table 4.7 Policy Updating Frequencies**

The above table indicates that the policy updating is different from one to another and it ranges from monthly to every five years for most of them. The frequency of updating the policy is dictated by the extent of the contents of the policy, which in turn governed by the size of the fleet and hence, by the size of the organization. In addition, the market condition changes may also influence the frequency of updating the policy.

The firms' policy changes normally as they grew in experience. The firm refines its practices, and adopts any improvement that seems to be necessary to the replacement manual or policy. The frequency of updating the policy need to be a statement on the equipment replacement manual to indicate when it is supposed to be revised and who should be involved on the periodic review of the policy manual.

An equipment replacement policy or manual contains elements or sections that are divided according to their functionality and contents. The National Association of Accountants identified the following elements for the equipment replacement policy; Forecasting the economic background, Long range planning, Identification of the alternatives, Time span of the

replacement decision, and organization of the equipment replacement policy. These elements were expanded and rewritten in the survey done for this study to suite the Saudi contractors investment environment and the proposed elements for the typical equipment replacement policy are; the policy organizational rules, the replacement and disposition need initiation, the optimum replacement time for an existing equipment, the departments involved on the replacement analysis, the minimum mark up price for evaluation, the factors that influence the replacement decision, the financial methods that are used for evaluation, and the policy toward new equipment models.

#### **4.4.1 Policy Organizational Rules**

The equipment replacement policy organizational rules are the guidelines that need to be established and written down to formulize the duties and rules of the equipment coordination group. This group is the organization, normally a unit within the maintenance or the equipment department that is responsible for coordinating and planning the equipment need and utilization.

The major activities for the coordination group include the followings:

1. Receive and evaluate the monitoring reports for owned equipment to determine the need for replacement analysis.
2. Receive requisitions for new construction equipment that might be needed from other departments like, project department, and evaluate the need for acquisition if available equipment cannot do the job or no enough equipment to be assigned for that project.
3. Arrange and plan the activities for the equipment evaluation team.
4. Schedule the periodic dates for evaluating the existing construction equipment.



5. Control and keep track of the replacement proposals and the replacement analysis reports.
6. Initiate and control all the replacement analysis forms.
7. Prepare final recommendation report for the equipment replacement analysis result in order for the top management to take the best replacement decision.

#### **4.4.2 Replacement and Acquisition Need Initiation**

Equipment acquisition can be initiated to replace inefficient equipment, replace inadequate equipment, or to add new equipment to cover the increasing demand for more equipment. Table 4.8 shows the distribution of the methods of determining the replacement time. It has been found that almost 85% of the participants replace the equipment when it becomes inefficient. Equipment is considered inefficient when the maintenance costs get more than the profits accrued from use. One-third of the participants replied that they perform an economic study to find out when to replace the equipment. Also, one-third of the participants replied that they replace the equipment when the financial picture is good. This indicates a tendency to invest in equipment whenever the firm finds itself in good financial position. Some of the participants indicated that they usually replace the equipment before a new job while a couple of participants indicated that they replace equipment before a major overhaul. This is costly practice, and only the big contractors can afford to do this. This is usually done if the project is a large one and equipment can be depreciated completely on the job. It has been found that the participants of all the grades replace their equipment when equipment becomes inefficient. This practice is also observed among the participants regardless of their grades. This seems to be the best practice, as the equipment is utilized fully before they are replaced.

<b>When to Replace The Equipment?</b>	<b>Frequency</b>	<b>Percent</b>
1. After Economic Study	8	38.10
2. Inefficient Equipment	18	85.71
3. Before a new Job	4	19.05
4. Before a Major Overhaul	4	19.05
5. When Equipment is Obsolete	5	23.81
6. Good Financial Picture	7	33.33

**Table 4.8      When to Replace Construction Equipment**

There are factors that determine the optimum replacement time for a piece of equipment after which the equipment replacement proposals need to be initiated and the replacement process shall start. Table 4.9 list these factors which include, generation of a report cost curve and replacement when a determined target value is achieved, replacement when cost of necessary repairs seems to be too high, and determination of the economic life of equipment and replacement at the end of this period.

<b>Methods to Determine Optimum Replacement Time</b>	<b>Frequency</b>	<b>Percent</b>
1. Generation of Cost Curve and Replacement When a Target is Reached	1	4.76
2. Replace When Cost of Necessary Repairs is Too High	16	76.19
3. Determine the Economic Life and replace at the End of This Period	3	14.29
4. No Response	1	4.76

**Table 4.9      Method to Determine Optimum Replacement Time**

Table 4.9 indicates that 76 percent of the participants replace their equipment when the cost of necessary repairs is too high. On the other hand, 14 percent determine the economic life of the equipment and replace at the end of this period. This indicates that most of the firms in Saudi

Arabia replace their equipment only when the cost of repairing them is too high. This is in agreement with the analysis of Table 4.8 before which indicate that the contractors replace their equipment when the maintenance cost is higher than the profit.

The economic life of equipment is the period of time, part of the physical life of the equipment, where the profit from using the equipment is more than the costs incurred by operating and maintaining it. Normally, the equipment manufacturer provides the physical life curve for the piece of equipment and the economic life can be determined from there.

*So, the decision is taken to replace the existing equipment when the age exceeds its economic life and it become inefficient.*

There are many factors to be considered when determining the economic life of an equipment. Table 4.10 presents the frequency distribution of the factors considered in determining the economic life of the equipment.

<b>Factors Determining Economic Life</b>	<b>Frequency</b>	<b>Percent</b>
1. Depreciation and replacement costs	9	42.86
2. Investment Costs	9	42.86
3. Maintenance and Repair Costs	16	76.19
4. Downtime Costs	15	71.43
5. Obsolescence Costs	7	33.33
6. Profit Accrued From Use	5	23.81

**Table 4.10 Factors Determining the Economic Life**

The majority of the participants consider the maintenance, repair, and the downtime costs as the most influential factors in determining the economic life of an equipment. The profits from the equipment are accrued during its working life. These profits constitute the earnings, while the maintenance and repair costs constitute the spending during the working life of the equipment.

As a piece of equipment gets old, the profits accrued from use decrease, while the maintenance and repair costs increase. When the repair costs exceed the profits, the equipment is termed as unprofitable to the firm, and hence it is disposed off.

Downtime costs are the consequential costs that result from the equipment failure during its operational use as detailed in section 2.3.7. Hence maintenance costs and downtime costs are the most influential factors in determining the life of the equipment. Depreciation, replacement, and investment costs are also considered important factors and about 42% of the participants consider them effective in determining the economic life of the equipment. Another factors like obsolescence costs and the profit accrued from the replacement are also considered by some of the participants to influence the economic life of the equipment but to a lesser degree. This might be due to the reward from these two factors is not high enough to be taken into consideration.

***So, the major factors that determine the economic life of equipment are the maintenance cost, the repair cost, and the downtime cost.***

Need for new equipment could be recognized and initiated at any level of the firm. Once, the need is recognized, it is communicated to the decision-makers via various methods. Table 4.11 shows the distribution of organizational level within the firm that initiates the need for equipment replacement among the participants. The results indicate that the majority of the proposals originate from the equipment department. Some proposals are initiated from replacement analysis team and some from the project management. The reasons for having most of the replacement proposals initiated by the equipment department might be due to the full involvement and knowledge of the equipment department about the equipment in question since they normally maintain historical records for each equipment.

<b>Organizational Level</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Replacement Analysis Team	2	9.52	2	9.52
2. Equipment Department	15	71.44	17	80.96
3. Financial Department	1	4.76	18	85.72
4. Project Manager	2	9.52	20	95.24
5. Others	1	4.76	21	100.00

Table 4.11 Who Initiate Replacement Proposals

#### 4.4.3 Frequency of Conducting the Replacement Analysis

The frequency of conducting the replacement analysis depend on the need for additional new equipment and how productive are the existing ones.

Existing equipment efficiency and productivity can be measured by evaluating the periodic cost and production reports. Evaluation of these cost and production reports can be done either on periodic bases or on demand bases. The periodic evaluation is scheduled periodic review for the equipment status to find out if the equipment is still in the economic life cycle or it need replacement. The demand evaluation is usually before a major overhaul or new project.

The need for new additional equipment can result from new projects or company expansions. It might be due to the lack of rental and leasing market in Saudi.

The company policy toward replacement or acquisition of additional new equipment may vary depending on the size of the company, the workload, the value of the equipment fleet, and the market situation.

Table 4.12 shows that grades I and II participant's policy of replacement does not change with the workload changes, but the grade III participants tend to change equipment more frequently when jobs are competitive. This may be because the grade III participants being smaller firms depend on contracts to buy new equipment. The other contractors having reasonable assets do

not have a change in policy. The common practice is then to consider the competition in the market when doing the replacement analysis.

<b>Frequency of Replacement</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. High Competitive Jobs	13	61.91	13	61.91
2. Low Competitive Jobs	2	9.52	15	71.43
3. Policy Does Not Change	4	19.05	19	90.48
4. No Response	2	9.52	21	100.00

**Table 4.12 Frequency of Replacement**

#### **4.4.4 Departments Involved in the Evaluation Process**

Once the equipment replacement request comes to the equipment replacement coordination group. The equipment replacement team will study and evaluate the replacement alternatives and suggest the best decision.

Table 4.13 indicates the departments that are involved in the evaluation process. It is found that equipment maintenance and project management are mostly involved in the replacement analysis. Equipment operations, financing, and purchasing departments are sometimes involved. It is clear that more than 50% of the participants involve all the five departments, listed in Table 4.13, in the evaluation process. These five departments are considered to have effective inputs to the evaluation process. The representative of each department need to be qualified, knowledgeable, and has enough experience in order to participate in the evaluation process. Each firm has it's own qualification requirements and rules to ensure that the evaluation team members are properly selected to that job.

<b>Department Name</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Equipment Operations	13	19.12	13	19.12
2. Equipment Maintenance	17	25.00	30	44.12
3. Project Management	15	22.06	45	66.18
4. Purchasing	11	16.18	56	82.35
5. Financial	12	17.65	68	100.00

**Table 4.13      Departments Involved In the Evaluation Process**

#### **4.4.5 Final Decision for Acquisition and Disposition**

After the quantitative and qualitative evaluations are done and it is decided to invest in particular equipment, it is the responsibility of the top management to take a final decision on the acquisition of new one and the disposition of some existing equipment whenever it seems to be required. The equipment replacement team will come up with the final recommendations after doing the analysis and will pass them to the top management. Tables 4.14 and 4.15 present the distribution of responsibility for making the final decision toward the acquisition and disposition. The president or the CEO of the company usually takes the final decision regarding the equipment acquisition and disposition regardless of the size of the participant. For some small volume investments, the project manager or the equipment manager takes the acquisition and disposition decision. The reasons for having the president to take the final decision on the equipment replacement or disposition might be due to the high value of the equipment which is considered as a major asset to the firm that need very thorough analysis before taken any decision.

<b>Responsibility</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. President (CEO)	15	71.43	15	71.43
2. Board of Directors	3	14.29	18	85.72
3. Project Manager	1	4.76	19	90.48
4. Equipment Manager	1	4.76	20	95.24
5. No Response	1	4.76	21	100.00

Table 4.14 Responsibility for Final Acquisition Decision

<b>Responsibility</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. President (CEO)	15	71.44	15	71.44
2. Board of Directors	1	4.76	16	76.20
3. Project Manager	1	4.76	17	80.96
4. Equipment Manager	2	9.52	19	90.48
5. No Response	2	9.52	21	100.00

Table 4.15 Responsibility for Final Disposition Decision

#### 4.4.6 Minimum Mark-up Price for Evaluation

A minimum size of equipment investment is set as a mark-up price for the quantitative evaluation of equipment investments. Investment proposals equal to or above this mark-up price are evaluated quantitatively to decide the feasibility of the investment. It is found that the contractors set a mark-up price upon which quantitative evaluation is imminent. The results indicate that the mark-up value for the participants range between SR 10 thousand to SR 3 million. The average investment size worthwhile a quantitative evaluation is SR 0.89 million.



#### **4.4.7 Analysis of Equipment Replacement Proposals**

Once the decision is made to evaluate the need for replacing existing equipment or to buy new one, the equipment replacement coordination group will made-up the team to do the analysis. The team will perform the evaluation based on the predefined objectives that are set by the coordination team. The following sections will shed some light on the required data to do the analysis and the financial evaluation method.

##### **4.4.7.1 Identification of Alternative Proposals**

It is evident that contractors search for replacement alternatives in order to go with the alternative that maximize the profit and reduce expenses and losses. The replacement coordination team will prepare and arrange the proposal of each alternative and make it ready for evaluation after gathering the required information and quotation from vendors or other organizations. Some of the major alternatives that may be considered are:

1. Remodel the present equipment
2. Buy new one
3. Buy used one
4. Continue with the old one

Table 4.16 shows that the majority of the participants search for and consider equipment replacement alternatives.

<b>Are Alternatives Searched?</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Yes	12	57.15	12	57.15
2. No	7	33.33	19	90.48
3. No Response	2	9.52	21	100.00

**Table 4.16 Search for Replacement Alternatives**

#### **4.4.7.2 Factors Evaluated on the Replacement Analysis**

There are two types of factors that may influence the replacement and need to be considered in the replacement analysis. The first type include the subjective or qualitative factors that have no sensible money value and would affect the company image on industry in addition to the effect on employees and environment. The second type includes the quantitative factors that can impact the company total cost and profit.

##### **4.4.7.2.1 Qualitative Factors That Influence Replacement Analysis**

Some of the subjective or qualitative factors that may be considered in the replacement evaluation process include employee morale, employee safety, environmental responsibility, image on industry and among others, and the management goals.

Table 4.17 gives score and ranks of these qualitative factors. The sum is equated by multiplying the score by the influence value on top of each column in order to balance the effect of each factor. The goals of management are to earn maximum profits on their investment. Since this is the primary aim of any profit making organization, this factor ranks first. Employee safety is the next important factor. It seems that the top management of the firms recognizes the importance of employee safety. Accidents have negative impact on the employee productivity and may cause losses to the company assets. The image of the company in industry and among others ranks as the third important factor. It seems that the firms care about their position among others and try to keep competition in order to be able to win new projects and to give good picture for the firm. Employee morale ranks as the forth-important factor, which indicate that the firms care about their employees in order not to impact their productivity. Environmental responsibility ranks the fifth and last factor to be considered in the evaluation process. This factor may not be considered

by every the firms since no governmental rules that set requirements and limits to protect the environment.

Qualitative Evaluation Factor	Score						
	VMJI	MJI	MNI	VMNI	NI		
	5	4	3	2	1	Sum	Rank
1. Employee Morale	5	2	8	4	1	66	4
2. Employee Safety	5	13	2	1	0	85	2
3. Environmental Responsibility	1	4	10	4	1	60	5
4. Image(In Industry & Among Others)	6	11	1	1	1	80	3
5. Management Goals	15	4	2	0	0	97	1

Table 4.17 Qualitative Evaluation Factors

#### 4.4.7.2.2 Quantitative Factors That Influence Replacement Analysis

As part of the analysis of the replacement proposals, there are some factors or variables that control and affect the result of the analysis. These quantitative factors are normally calculated for each proposal, including the existing equipment in order to use their result on the comparison or evaluation method or to use it as a stand-alone index when doing the final decision. These quantitative factors include inflation, Escalation, Downtime cost, Obsolescence, Depreciation, Time value of money, Salvage value, and Cost records.

Table 4.18 presents the importance of each of the above factors on the participant replacement decision. It seems that contractors consider the downtime cost and obsolescence as the highest and most effective factors. Also, the time value of money and the salvage value have a considerable value on the evaluation.

Quantitative Evaluation Factor	Score						Sum	Rank
	VMJI	MJI	MNI	VMNI	NI			
	5	4	3	2	1			
1. Inflation	1	2	6	7	3	48	7	
2. Escalation	1	3	7	7	1	53	6	
3. Downtime Costs	12	5	3	0	0	89	1	
4. Obsolescence	5	11	3	2	0	82	2	
5. Depreciation	4	9	4	4	0	76	3	
6. Time Value of Money	4	6	5	3	2	67	4	
7. Salvage Value	0	5	12	3	0	62	5	

Table 4.18 Quantitative Evaluation Factors

Now let's talk about the definition of these factors, their influence, and the way to calculate their values in more detail.

#### a. Ownership Cost

Ownership cost is how much does the equipment cost the owner on annual bases and how much is the annual decrease on the value of that equipment. It consists of the investment cost and the depreciation on the value of the equipment.

The investment cost is how much is the initial cost of the equipment to the owner. It also includes the interest on the money invested, taxes (if applicable), storage, and delivery cost. Using the total initial cost, the life of the equipment in years, and the salvage value, the annual average value of the equipment can be calculated for each replacement proposal using equations number 10 and 11 on section 2.3.1.

The depreciation cost is how much is the loss in the value of the equipment over time. This is generally caused by wear and tear from use, deterioration, obsolescence, and reduced need. The depreciation cost can be found using one of the four methods listed below on Table 4.19.

<b>Depreciation Accounting Method</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Straight Line	11	52.38	11	52.38
2. Double Declining balance	1	4.76	12	57.14
3. Sum of Years digits	1	4.76	13	61.90
4. Percent of Life	8	38.10	21	100.00

Table 4.19 Depreciation Accounting Method

It looks that the contractors use different methods for calculating the depreciation of their equipment. The majority of the participants use either the straight-line method or the percent of life method for determining the depreciation of the equipment. Only one contractor uses the double declining balance method and one uses the sum of year's digits method.

The above methods allow for fast depreciation of the equipment. So, the contractors might depreciate their equipment in a shorter time and replace them more frequently than others.

Hence the straight-line method and the sum of year's digits are more popular ones for calculating the depreciation due to their simplicity and ease of use.

#### **b. Inflation**

Inflation is the annual decrease in the value of money or the additional money on the real price of the equipment due to reduced value of the currency. The consumer price index (CPI) is the most common measure for the total effect of costs on equipment ownership and operation. It is generally used on union agreements regarding wages to determine the cost living increases.

The effects of inflation can be incorporated to the replacement analysis by adjusting the cash flow, adjusting the interest rate, or adding it as an independent factor.

### **c. Salvage Value**

The salvage value is a calculated value for the future worth of the equipment at the disposal time. When old equipment is sold, the firm gains from the resale. This is called the obtainable salvage value. Since the amount gained from the sale can be used for financing its replacement, the net resale price generally influences the replacement decision.

There are many ways for disposing off equipment. Table 4.20 shows the distribution of methods of disposing the equipment. The majority of the participants sale their equipment in auctions. A third of the participants sell off their equipment to others. Hence, it can be seen that the auction sale is an advantageous to both the seller and the buyer. The bigger contractor can sell off the equipment and get a good salvage or resale value to buy better equipment and avoids obsolescence. The small contractor who cannot afford to buy the costly equipment first-hand will find it cheaper to buy used one.

<b>Disposition Method</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Trade to Dealer	1	4.76	1	4.76
2. Auction Sale	14	66.67	15	71.43
3. Sell to Others	6	28.57	21	100.00

Table 4.20 Methods of Disposition

### **d. Time Value of Money**

Time value of money is the consideration of time when analyzing the costs and rewards of an equipment. Cash flow method is a good example of using the time adjusted expenses and benefits.

#### e. Obsolescence

Obsolescence is the increase on the operating cost and the decrease on the resale value. That is due to many reasons as listed in Table 4.21. Most of the participants consider the equipment obsolete when the equipment exceeded its economic life since the risk of equipment failure will increase and if it happens it might have big economical impact on them. About one third consider the equipment obsolescence also when the manufacturer is out of business or does not support that equipment any more. The vision toward new equipment is not to consider the current equipment obsolete.

<b>Cause of Obsolescence</b>	<b>Frequency</b>
1. Manufacturer Out of Business	8
2. Availability of Better New Models	5
3. Equipment Economic Life Exceeded	15

Table 4.21 Causes of Obsolescence

Table 4.22 shows the annual obsolescence rate that occurs in the participant's construction equipment. About 50% of the participants estimated the obsolescence rate to be about 10%. This is a very high rate that indicates how fast construction equipment gets obsolete.

<b>Annual Obsolescence Rate (%)</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
0 to 5	4	19.05	4	19.05
6 to 10	11	52.38	15	71.43
11 to 15	5	23.81	20	95.24
No Response	1	4.76	21	100.00

Table 4.22 Annual Obsolescence Rate

#### **f. Downtime Costs**

The downtime cost is the costs that arise from an equipment failure. It can be divided into two categories. The first category is the tangible cost of labor, material, and other resources needed to repair the equipment. The second category includes all the intangible or consequential costs that arise from the failure and that include loose of production cost, delay or impact on the schedule, and any other impacts on the organization as a whole.

#### **4.4.7.3 Financial Analysis of Equipment Replacement Proposals**

The financial analysis of the equipment replacement proposals is the quantitative evaluation of the proposals money values. It is the comparison of the expenses and revenues of each proposal over pre-defined time span to find out the best replacement proposal. The economic comparison of the alternative cash flows can be either for the net cash flows or for the disbursements (expenses) of the alternatives. Table 4.23 shows the distribution of the comparison methods over the participants. The majority of the respondents compare the net cash flows of the alternatives, which include the disbursements and the revenues, while only 19% depend on the disbursements on the comparison.

Since, a consideration of the net cash flows involves the calculations of the difference between the receipts and the costs of the different alternatives; most of the firms tend to consider the net cash flows instead of considering the disbursements of alternatives. This is also the practice of whether the participants have written policies or not.



<b>Comparison Way</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Disbursements of Alternatives	4	19.05	4	19.05
2. Net Cash Flows	7	33.33	11	52.38
3. No Response	10	47.62	21	100.00

**Table 4.23 Comparison for Quantitative Evaluation**

The tendency of the contractors above to do the net cash flow analysis and to see the revenue results might be due to important of this information to them since the equipment is a major asset in the firm and a replacement need to have good money value before it can be taken.

The receipts of various proposals can be found using any of the methods listed on Table 4.24.

<b>Determination of Proposals Receipts</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Directly allocate revenue to equipment investment	6	28.57	6	28.57
2. Use rental rates from local equipment dealers	2	9.52	8	38.09
3. Using rental rates as suggested by governmental agencies	0	0	8	38.09
4. Calculating internal rates based on in-house data	12	57.15	20	95.24
5. No Response	1	4.76	21	100.00

**Table 4.24 Determination of Proposals Receipts**

About 57% of the participants calculate internal rates based on in-house data while 28% directly allocate revenues to equipment proposals. These two methods are the commonly used ones while others are really used.

During the financial evaluation of the received equipment replacement proposals, the common practice is to translate all the available information about the replacement alternatives into

sensible numbers and figures in order to use sum assumptions to make the comparison more fair and meaningful. The analysis start with establishing a cash flow for each alternative where the amount of money spent or gained on the investment will be presented on the cash flow diagram. In addition, the firm needs to establish the Minimum Attractive Rate of Return (MARR), which is the minimum interest rate that the company requires to gain from the investment. Also, the following two assumptions need to be considered (Thuesen, 1993):

1. When comparing alternatives with unequal lives, assume that all the alternatives have the same time span for comparison. The time span over which alternatives to be compared are usually refer to as the study period or the planning horizon. This study period may be set by the company policy or it may be determined by the time span over which reasonably accurate cash flow estimates can be a basis for determining the study period.
2. The method of treating the existing equipment cash flow should be the same as that used for the new alternatives. Also, the value of the existing equipment that should be used in the analysis is not what it cost when it was originally purchased but what it is worth at the present time. Thus the existing equipment sunk cost is irrelevant to any replacement decision.

#### **4.4.7.3.1 Cash Flow Analysis**

To aid in identifying and recording the economic effects of investment alternatives, a graphical description of each alternative's cash transactions may be used. This graphical descriptor, referred to as cash flow diagram, can provide the information necessary for analyzing a replacement proposal. The details of the cash flow diagram and how it can be used are detailed in section 2.3.4.

#### **4.4.7.3.2 Minimum Attractive Rate of Return (MARR)**

The Minimum Attractive Rate of Return (MARR) is a cut-off return representing the yield on investments that is considered as a minimum acceptable return.

Over the years there has been much discussion about how to select the minimum rate of return. Unfortunately, there is yet to be offered a completely satisfactory method for precisely determining this rate. Because the rate that is selected represents the firm's profit objectives, it is usually based on the judgment of the firm's senior management. This judgment is in turn based on the management's view of the firm's future opportunities along with the firm's financial situation. [Thuesen, 1993]

Table 4.25 presents the commonly used method to determine the minimum rate of return and the participant's distribution among the methods. About 42 percent of the participants use management determine target rate of return and about 28 percent use their historical rate of return. The cost of specific source of fund and the weighted cost of source of funds are not commonly used methods.

<b>How to Determine the Minimum Rate of Return?</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Cost of Specific Source of Funds	2	9.52	2	9.52
2. Weighted Cost of Sources of Funds	2	9.52	4	19.04
3. Management Determine Target Rate of Return	9	42.86	13	61.90
4. Firm's Historical Rate of Return	6	28.58	19	90.48
5. No Response	2	9.52	21	100.00

**Table 4.25 Determination of the Minimum Rate of Return**

Selecting proper minimum rate of return is very important and can impact the selection of the best equipment replacement alternative.

If the minimum rate of return is selected too high, many proposals that have good returns may be rejected. On the other hand, a rate that is too low may allow the acceptance of proposals that are marginally productive or result in economic loss. Thus, when choosing the minimum rate of return there is a trade-off between being too selective or not being selective enough.

#### **4.4.7.4 Financial Evaluation of equipment replacement Proposals**

The financial evaluation can be done using one of the following methods: the net present value method, the payback period method, the internal rate of return method, the annual cost minimization method, the total cost minimization method, the economic life method, and the profitability index method. The cash flow is normally prepared for each alternative and used as the base to perform the analysis.

The following material will discuss in more detail these evaluation methods. The evaluation will begin by an introduction that defines the method and the objectives from using it. That will be followed by the conventional presentation that is commonly used for the method and how to perform the calculations to come up with the decision criteria. Then the decision criteria for each method will be stated. The decision criterion is a rule or procedure that prescribes how to select investment alternatives so that certain objectives can be achieved.

Finally, an extensive study for the method characteristics and effectiveness will be presented.

A list of criteria that found to be most effective and valuable in evaluating the financial replacement methods was passed to the participants in order to get their inputs toward the importance and value of each criteria on the respective method. The participants response along

with the literature review material on each method will be used as the base to describe the characteristics and to evaluate the effectiveness of each method.

At the end of this section and based on the participants responses to the questions on the effectiveness of the method, a value will be given to each method in order to find out the commonly used method that is considered by the participants as the most effective evaluation method.

To simplify the evaluation of the methods, each evaluation question on the equipment effectiveness will be given the same weight and the value will be equal to the frequency of the responses to each criterion. All the questions are considered positive Responses that add to the value of the method with exception of question number three that is considered negative and will deduct points from the value of the method.

#### **4.4.7.4.1 The Net Present Value (NPV) Method**

The Net Present Value (NPV) is the net equivalent amount at the present time that represents the difference between the equivalent expenses and the equivalent revenues for an alternative's cash flow for selected interest rate and investment duration.

The prime objective for the method is to indicate if the alternative is profitable and worth the investment or not. When the proposal NPV is positive, the proposal promises an acceptable rate of return and considered profitable. If the NPV is negative, the proposal is considered non-profitable one.

## **NPV Characteristics and Effectiveness**

The survey results indicate that seven participants seem to be using the NPV method and as per Table 4.26, the following is the evaluation of the method characteristics:

1. **Simplicity:** only one participant indicated the simplicity of the method. The NPV is one of the simple methods used and does not require extensive knowledge of math or economy.
2. **Input Data Available:** Three participants indicated that the required data for the NPV method are available. The required input data for the NPV method are the revenues, expenses, the investment period, and the interest rate. The revenues and expenses are the variables that need to be equated. Inputs to estimate these revenues and expenses are needed from the manufacturer and the company that will be using the equipment. The cash flow formula is used to regulate these expenses and revenues and discount them based on the time value of money, the interest rate, and the investment period. The interest rate and the investment period are usually estimated by the company based on their financial and planning objectives.
3. **Require Excessive Knowledge of Accounting:** Two participants indicated that the NPV method requires excessive knowledge of accounting. The NPV method does not require excessive knowledge of accounting since all the required information are pre-defined and formulas are available for the calculations.
4. **Guideline Range is Available:** Only one participant indicated that the guidelines for the NPV method are available. Since the calculation formulas are pre-defined, only the interest rate and the investment period need guidelines. The interest rate and the investment period normally follow the predefined company's guideline ranges and values.

5. **Measure the Future Risk Period:** Two participants indicated that the method measure the future risk period. The NPV method depends on the investment period and does not indicate or measure the future risk period. However, if the investing company consider the investment period as the risk period then the NPV can indicate indirectly the future risk period.
6. **Measure the Rate of Return:** Four participants indicted that the method measure the rate of return. The NPV method does not measure the rate of return of the investment. However, if the investing company consider the interest rate as the expected rate of return then the method can give some indication to the rate of return of the alternative.
7. **Measures the Worth of the Bid:** Three participants indicted that the method measures the worth of the bid. One of the objectives of using the NPV method is to measure the worth of the bid and indicate if the replacement alternative worth investing or not.
8. **Consider the Time Value of Money:** Three of the participants indicated that the method consider the time value of money. Actually the method consider the time value of money through the intrest rate that need to be estimated as an input data. The selected interest rate does consider the time value of money.
9. **Consider the Expected Salvage Value:** Two participants indicated that the method consider the expected salvage value. The NPV method consider the salvage value since the investing company need to estimate the salvage value for the equipment at the end of the investment period and evaluate it as part of the equipment cash flow.
10. **Consider Obsolescence and Deterioration:** Two participants indicated that the NPV method consider obsolescence and deterioration of the equipment. The method does consider osolescence through the salvage value that need to be estimated for the equipment ate the

end of the investment period. Also, the method consider the deterioration through the increasing annual expenses and the decreasing annual revenues.

11. Determine the Expected Economic Life: three out of the seven participants that are using the method stated that the method determine the expected economic life of the equipment. The NPV method does not determine the expected economic life of the equipment. However, if the investing company consider the estimated life of the equipment as the investment period, then that can give indication on the expected economic life.

Table 4.26 indicates that the NPV overall value is twenty-two points. This value is based on the responses of the seven users for the NPV method. If all the seven users respond positively to each question as a value or characteristic of the NPV method, the overall value will be  $7 \times 10 = 70$  points. The value or weight of question number 3 is considered as zero when it is positive. Therefore only ten questions are considered to get the overall value of the method. So, the cumulative value for the NPV method among the seven users is about  $(22/70 = 31.4\%)$  of the maximum expected weight.



<b>Criteria</b>	<b>Frequency</b>	<b>Percent</b>	<b>Value</b>	<b>Cumulative Value</b>
1. Simplicity	1	4.76	1	1
2. Input Data Available	3	14.29	3	4
3. Require Excessive Knowledge of Accounting	2	9.52	2	2
4. Guideline Range is Available	1	4.76	1	3
5. Measure the Future Risk Period	2	14.29	2	5
6. Measure the Rate of Return	4	19.05	4	9
7. Measure the Worth of the Bid	3	14.29	3	12
8. Consider the Time Value of Money	3	14.29	3	15
9. Consider the Expected Salvage Value	2	9.52	2	17
10. Consider Obsolescence and Deterioration	2	9.52	2	19
11. Determine the Expected Economic Life	3	14.29	3	22
<b>Overall Method Value</b>				<b>22</b>

Table 4.26 The NPV Method Effectiveness

In general, the NPV is used only to indicate if the alternative is profitable or not and never used to take replacement decision.

#### 4.4.7.4.2 The PayBack Period (PBP) Method

The payback period (PBP) is the period of time after which the investor will recover his money back or the time required until the equivalent revenues exceed the equivalent capital overlays.

The prime objective for the method is to measure how many years the invested money will be in risk.

Normally, the company will set a predetermined number of years where the proposed equipment payback period should be less than or equal to that predetermined number in order to consider that equipment a worthwhile investment.

## **PBP Characteristics and Effectiveness**

The survey results indicate that seven participants seem to be using the PBP method and as per Table 4.27, the following is the evaluation of the method characteristics:

1. **Simplicity:** All the seven participants that are using the method indicated the simplicity of the PBP method. The PBP is one of the simple methods used and does not require extensive knowledge of math or economy.
2. **Input Data Available:** Five participants indicated that the required data for the PBP method are available. The required input data for the PBP method are the revenues, expenses, and the interest rate. The revenues and expenses are the variables that need to be equated. Inputs to estimate these revenues and expenses are needed from the manufacturer and the company that will be using the equipment. The cash flow formula is used to regulate these expenses and revenues and discount them based on the time value of money, the interest rate, and the investment period. The interest rate is usually estimated by the company based on its financial and planning objectives.
3. **Require Excessive Knowledge of Accounting:** None of the seven participants that are using the method indicated that the PBP method requires excessive knowledge of accounting. The PBP method does not require excessive knowledge of accounting since all the required information are pre-defined and formulas are available for the calculations.
4. **Guideline Range is Available:** Only one participant indicated that the guidelines for the PBP are available. Since the calculation formulas are pre-defined, only the interest rate needs guidelines. The interest rate normally follows the predefined company's guideline ranges and values.

5. **Measure the Future Risk Period:** Four participants indicated that the method measure the future risk period. The PBP does indicate and measure the future risk period. It is used by many company's to indicate how long is the invested many on risk.
6. **Measure the Rate of Return:** Five of the seven participants that are using the method indicted that the method measure the rate of return. The PBP method does not measure the rate of return of the investment. However, if the investing company consider the interest rate as the expected rate of return then the method can give some indication to the rate of return of the alternative.
7. **Measures the Worth of the Bid:** Only one participant indicted that the method measures the worth of the bid. There are no indications on the method to the worth of the bid.
8. **Consider the Time Value of Money:** None of the participants indicated that the method consider the time value of money. Actually the method consider the time value of money through the intrest rate that need to be estimated as an input data. The selected interest rate does consider time value of money.
9. **Consider the Expected Salvage Value:** Only one participant indicated that the method consider the expected salvage value. The PBP method consider the salvage value since the investing company need to estimate the salvage value for the equipment at the end of the investment period and evaluate it as part of the equipment cash flow.
10. **Consider Obsolescence and Deterioration:** Three participants indicated that the PBP method consider obsolescence and deterioration of the equipment. The PBP method does consider osolescence through the salvage value that need to be estimated for the equipment ate the end of the investment period. Also, the method consider the deterioration through the increasing annual expenses and the decreasing annual revenues.

11. Determine the Expected Economic Life: three participants stated that the method determine the expected economic life of the equipment. The PBP method does not determine the expected economic life of the equipment.

Criteria	Frequency	Percent	Value	Cumulative Value
1. Simplicity	7	33.33	7	7
2. Input Data Available	5	23.81	5	12
3. Require Excessive Knowledge of Accounting	0	0	0	12
4. Guideline Range is Available	1	4.76	1	13
5. Measure the Future Risk Period	4	19.05	4	17
6. Measure the Rate of Return	5	23.81	5	22
7. Measure the Worth of the Bid	1	4.76	1	23
8. Consider the Time Value of Money	0	0	0	23
9. Consider the Expected Salvage Value	1	4.76	1	24
10. Consider Obsolescence and Deterioration	3	14.29	3	27
11. Determine the Expected Economic Life	3	14.29	3	30
<b>Overall Method Value</b>				<b>30</b>

Table 4.27 The PBP Method Effectiveness

Table 4.27 indicates that the overall value of the PBP method is thirty points. This value is based on the responses of the seven users for the PBP method. If all the seven users respond positively to each question as a value or characteristic of the PBP method, the overall value will be  $(7 \times 10 = 70)$  points. The value or weight of question number 3 is considered as zero when it is positive. Therefore only ten questions are considered to get the overall value of the method. So, the actual value for the PBP method among the seven users is about  $(30/70 = 43\%)$  of the maximum expected weight.

In General the PBP method is used to calculate how long is the invested money will be in risk and to estimate the number of years after which the investor will recover his money back..

#### **4.4.7.4.3 The Internal Rate of Return (IRR) Method**

The internal rate of return (IRR) is the interest rate that causes the equivalent revenues of a cash flow to equal the equivalent expenses. In other words, it is the interest rate (i) that reduces the present worth of a series of revenues and expenses for the cash flow to zero. In economics, the IRR represents the percentage or rate earned on the unrecovered balance of the investment.

#### **IRR Characteristics and Effectiveness**

The survey results indicate that three participants seem to be using the IRR method and as per Table 4.28, the following is the evaluation of the method characteristics:

1. **Simplicity:** Two participants indicated the simplicity of the method. The IRR is one of the simple methods used and does not require extensive knowledge of in math or economy.
2. **Input Data Available:** All the three participants that are using the method indicated that the required data for the IRR method are available. The required input data to the IRR are the revenues, expenses, and the investment period. The revenues and expenses are the variables that need to be equated. Inputs to estimate these revenues and expenses are needed from the manufacturer and the company that will be using the equipment. The cash flow formula is used to regulate these expenses and revenues and discount them based on the time value of money, the interest rate, and the investment period. The investment period is usually estimated by the company based on its financial and planning objectives.

3. **Require Excessive Knowledge of Accounting:** None of the three participants that are using the method indicated that the IRR method requires excessive knowledge of accounting. The IRR method does not require excessive knowledge of accounting since all the required information are pre-defined and formulas are available for the calculations.
4. **Guideline Range is Available:** Only one participant indicated that the guidelines for the IRR are available. Since the calculation formulas are pre-defined, only the investment period need guidelines. The investment period normally follows the predefined company's guideline ranges and values.
5. **Measure the Future Risk Period:** None of the three participants that are using the IRR method indicated that the method measure the future risk period. The IRR method depends on the investment period and does not indicate or measure the future risk period. However, if the investing company consider the investment period as the risk period then the IRR can indicate indirectly the future risk period.
6. **Measure the Rate of Return:** Two of the three participants that are using the method indicted that the method measure the rate of return. The main objective for the IRR method is to measure the rate of return of the investment alternative. That is by finding the minimum value for the variable (i) that satisfy equation (8) on section (a) above that represents the IRR.
7. **Measures the Worth of the Bid:** Two of the three participants that are using the IRR method indicted that the method measures the worth of the bid. There are no indications on the method to the worth of the bid.
8. **Consider the Time Value of Money:** One of the participants indicated that the method consider the time value of money. Actually the method consider the time value of money

through the interest rate that need to be estimated as an input data. The selected interest rate does consider the time value of money.

9. **Consider the Expected Salvage Value:** Two participants indicated that the method consider the expected salvage value. The IRR method consider the salvage value since the investing company need to estimate the salvage value for the equipment at the end of the investment period and evaluate it as part of the equipment cash flow.
10. **Consider the Obsolescence and Deterioration:** None of the three participants that are using the method indicated that the method consider obsolescence and deterioration of the equipment. The method does consider obsolescence through the salvage value that need to be estimated for the equipment at the end of the investment period. Also, the method consider the deterioration through the increasing annual expenses and the decreasing annual revenues.
11. **Determine the Expected Economic Life:** Two of the three participants that are using the method stated that the method determine the expected economic life of the equipment. The NPV method does not determine the expected economic life of the equipment. However, if the investing company consider the estimated life of the equipment as the investment period, then that can give indication on the expected economic life.

Criteria	Frequency	Percent	Value	Cumulative Value
1. Simplicity	2	9.52	2	2
2. Input Data Available	3	19.05	3	5
3. Require Excessive Knowledge of Accounting	0	0	0	5
4. Guideline Range is Available	1	4.76	1	6
5. Measure the Future Risk Period	0	0	0	6
6. Measure the Rte of Return	2	9.52	2	8
7. Measure the Worth of the Bid	2	9.52	2	10
8. Consider the Time Value of Money	1	4.76	1	11
9. Consider the Expected Salvage Value	2	9.52	2	13
10. Consider Obsolescence and Deterioration	0	0	0	13
11. Determine the Expected Economic Life	2	9.52	2	15
<b>Overall Method Value</b>				<b>15</b>

Table 4.28 The IRR Method Effectiveness

Table 4.28 indicates that the overall value of the IRR method is fifteen points. This value is based on the responses of the three users for the IRR method. If all the three users respond positively to each question as a value or characteristic of the IRR method, the overall value will be  $(3 \times 10 = 30)$  points. The value or weight of question number 3 is considered as zero when it is positive. Therefore only ten questions are considered to get the overall value of the method. So, the actual value for the IRR method among the three users is about  $(15/30 = 50\%)$  of the maximum expected weight.

In general, the IRR method is used to find the minimum expected rate of return for the investment proposals over the investment period.



#### **4.4.7.4.4 The Annual Cost Minimization (ACM) Method**

The Annual Cost Minimization (ACM) method can be defined as finding the annual equivalent of all the costs associated with an alternative and selecting the alternative that has the minimum annual cost.

#### **ACM Characteristics and Effectiveness**

Since none of the participants uses the ACM method, the effectiveness will be determined based on the literatures review.

1. **Simplicity:** The ACM is not complicated method and easy to use.
2. **Input Data Available:** The required input data for the ACM method is the expenses, the investment period, and the interest rate. The expenses are the variables that need to be equated. Inputs to estimate these expenses are needed from the manufacturer and the company that will be using the equipment. The cash flow formula is used to regulate these expenses and discount them based on the time value of money, the interest rate, and the investment period. The interest rate and the investment period are usually estimated by the company based on its financial and planning objectives.
3. **Require Excessive Knowledge of Accounting:** The ACM method does not require excessive knowledge of accounting since all the required information are pre-defined and formulas are available for the calculations.
4. **Guideline Range is Available:** Since the calculation formulas are pre-defined, they are the guidelines for the method. The method does not seem to be widely used.
5. **Measures the Future Risk Period:** The ACM method depends on the investment period and does not indicate or measure the future risk period. However, if the investing company

consider the investment period as the risk period then the ACM can indicate indirectly the future risk period.

6. **Measure the Rate of Return:** The ACM method does not measure the rate of return of the investment alternative.
7. **Measures the Worth of the Bid:** There are no indications on the method to the worth of the bid.
8. **Consider the Time Value of Money:** Actually the method consider the time value of money through the interest rate that need to be estimated as an input data. The selected interest rate does consider the time value of money.
9. **Consider the Expected Salvage Value:** The ACM method does not consider the salvage value since it uses the equipment costs and expenses on the calculation and does not consider any revenues.
10. **Consider Obsolescence and Deterioration:** The method does not consider the equipment obsolescence on the calculation. However, it considers the deterioration through the increasing annual expenses.
11. **Determine the Expected Economic Life:** The ACM method does not determine the expected economic life of the equipment. The ACM method does not determine the expected economic life of the equipment. However, if the investing company consider the estimated life of the equipment as the investment period, then that can give indication on the expected economic life.

The ACM consider only the associated costs and does not pay any attention to the revenues that might be gained from the equipment utilization. That might be one of the major disadvantages of the ACM method that reduces the use of the method.

#### **4.4.7.4.5 The Total Cost Minimization (TCM) Method**

The Total Cost Minimization (TCM) method can be defined as the sum of all the costs for an equipment over the investment period and then selecting the alternative that has the minimum total cost.

#### **TCM Characteristics and Effectiveness**

The survey results indicate that two participants seem to be using the TCM method and as per Table 4.29, the following is the evaluation of the method characteristics:

1. **Simplicity:** the two participants indicated the simplicity of the method. The TCM is not difficult and simple to use.
2. **Input Data Available:** The two participants indicated that the TCM required data are not available. The required input data for the TCM method are the expenses, the investment period, and the interest rate. The expenses are the variables that need to be equated. Inputs to estimate these expenses are needed from the manufacturer and the company that will be using the equipment. The cash flow formula is used to regulate these expenses and discount them based on the time value of money, the interest rate, and the investment period. The interest rate and the investment period are usually estimated by the company based on their financial and planning objectives.
3. **Require Excessive Knowledge of Accounting:** Both participants that are using the method indicated that the TCM method requires excessive knowledge of accounting. The TCM method does not require excessive knowledge of accounting since all the required information are pre-defined and formulas are available for the calculations.

4. **Guideline Range is Available:** Only one participant indicated that the guidelines for the TCM are available. Since the calculation formulas are pre-defined, only the interest rate and the investment period need guidelines. The interest rate and the investment period normally follow the predefined company's guideline ranges and values.
5. **Measure the Future Risk Period:** One participant that are using the TCM method indicated that the method measure the future risk period. The TCM method depends on the investment period and does not indicate or measure the future risk period. However, if the investing company consider the investment period as the risk period then the TCM can indicate indirectly the future risk period.
6. **Measure the Rate of Return:** None of the two participants that are using the method indicted that the method measure the rate of return. The TCM method does not measure the rate of return of the investment. However, if the investing company consider the interest rate as the expected rate of return then the method can give some indication to the rate of return of the alternative.
7. **Measures the Worth of the Bid:** Only one participant indicted that the method measures the worth of the bid. There are no indications on the method to the worth of the bid.
8. **Consider the Time Value of Money:** Only one participant indicated that the method consider the time value of money. Actually the method consider the time value of money through the intrest rate that need to be estimated as an input data. The selected interest rate does consider the time value of money.
9. **Consider the Expected Salvage Value:** Only one participant indicated that the method consider the expected salvage value. The TCM method does not consider the salvage value since it consider only the costs and not the revenues in the calculations.

10. Consider Obsolescence and Deterioration: One of the two participants that are using the method indicated that the method consider obsolescence and deterioration of the equipment. The method does not consider obsolescence but it partially consider deterioration through the increased expenses and maintenance costs.
11. Determine the Expected Economic Life: One of the two participants that are using the method stated that the method determine the expected economic life of the equipment. The TCM method does not determine the expected economic life of the equipment.

Criteria	Frequency	Percent	Value	Cumulative Value
1. Simplicity	2	9.52	1	1
2. Input Data Available	0	0	0	1
3. Require Excessive Knowledge of Accounting	0	0	0	1
4. Guideline Range is Available	1	4.76	1	3
5. Measure the Future Risk Period	1	4.76	1	4
6. Measure the Rate of Return	0	0	0	4
7. Measure the Worth of the Bid	1	4.76	1	5
8. Consider the Time Value of Money	1	4.76	1	6
9. Consider the Expected Salvage Value	1	4.76	1	7
10. Consider Obsolescence and Deterioration	1	4.76	1	8
11. Determine the Expected Economic Life	1	4.76	1	9
<b>Overall Method Value</b>				<b>9</b>

Table 4.29 The TCM Method Effectiveness

Table 4.29 indicates that the overall value of the TCM method is nine points. This value is based on the responses of the two users for the TCM method. If all the seven users respond positively to each question as a value or characteristic of the TCM method, the overall value will be  $(2 \times 10 = 20)$  points. The value or weight of question number 3 is considered as zero when it is

positive. Therefore only ten questions are considered to get the overall value of the method. So, the actual value for the TCM method among the seven users is about  $(9/20 = 45\%)$  of the maximum expected weight.

#### **4.4.7.4.6 The Economic Life (EL) Method**

The Economic Life (EL) is the optimum replacement period or the minimum cost life where the total annual revenues equivalent will be higher than the total annual expenses equivalent.

Generally, the equipment manufacturer estimates the economic life for the equipment by providing the equipment performance curve. However, this duration will be affected by the equipment use and may vary drastically based on how good is the maintenance program and how good is the equipment utilization.

#### **EL Characteristics and Effectiveness**

The survey results indicate that nine participants seem to be using the EL method and as per Table 4.30, the following is the evaluation of the method characteristics:

1. **Simplicity:** Seven participants indicated the simplicity of the method. The EL is one of the simple methods used and does not require extensive knowledge of math or economy.
2. **Input Data Available:** Eight participants indicated that the required data for the EL method are available. The required input data for the EL method are the revenues, expenses, and the interest rate. The revenues and expenses are the variables that need to be equated. Inputs to estimate these revenues and expenses are needed from the manufacturer and the company that will be using the equipment. The cash flow formula is used to regulate these expenses and revenues and discount them based on the time value of money and the interest rate. The

interest rate is usually estimated by the company based on their financial and planning objectives.

3. **Require Excessive Knowledge of Accounting:** Three participants indicated that the EL method requires excessive knowledge of accounting. The EL method does not require excessive knowledge of accounting since all the required information are pre-defined and formulas are available for the calculations.
4. **Guideline Range is Available:** Three participants indicated that the guidelines for the EL are available. Since the calculation formulas are pre-defined, only the interest rate and the investment period need guidelines. The interest rate and the investment period normally follow the predefined company's guideline ranges and values.
5. **Measure the Future Risk Period:** Four participants that are using the EL method indicated that the method measure the future risk period. The EL method is sometimes considered as the future risk period.
6. **Measure the Rate of Return:** Five participants indicted that the method measure the rate of return. The method does not measure the rate of return.
7. **Measures the Worth of the Bid:** Three participants indicted that the method measures the worth of the bid. There are no indications on the method to the worth of the bid.
8. **Consider the Time Value of Money:** Three participants indicated that the method consider the time value of money. Actually the method consider the time value of money through the interest rate that need to be estimated as an input data. The selected interest rate does consider the time value of money.
9. **Consider the Expected Salvage Value:** Two participant indicated that the method consider the expected salvage value. The EL method consider the salvage value since the investing

company need to estimate the salvage value for the equipment at the end of the investment period and evaluate it as part of the equipment cash flow.

10. Consider Obsolescence and Deterioration: Five participants indicated that the method consider obsolescence and deterioration of the equipment. The method does consider obsolescence through the salvage value that need to be estimated for the equipment at the end of the investment period. Also, the method consider the deterioration through the increasing annual expenses and the decreasing annual revenues.
11. Determine the Expected Economic Life: All the nine participants stated that the method determine the expected economic life of the equipment. The main objective for the method is to find the expected economic life for the alternative equipment.

<b>Criteria</b>	<b>Frequency</b>	<b>Percent</b>	<b>Value</b>	<b>Cumulative Value</b>
1. Simplicity	7	33.33	7	7
2. Input Data Available	6	28.57	6	13
3. Require Excessive Knowledge of Accounting	3	14.29	3	10
4. Guideline Range is Available	3	14.29	3	13
5. Measure the Future Risk Period	4	19.05	4	17
6. Measure the Rate of Return	5	23.81	5	22
7. Measure the Worth of the Bid	3	14.29	3	25
8. Consider the Time Value of Money	3	14.29	3	28
9. Consider the Expected Salvage Value	2	9.52	2	30
10. Consider Obsolescence and Deterioration	5	23.81	5	35
11. Determine the Expected Economic Life	9	42.86	9	44
<b>Overall Method Value</b>				<b>44</b>

Table 4.30 The EL Method Effectiveness



Table 4.30 indicates that the overall value of the EL method is forty-four points. This value is based on the responses of the nine users for the EL method. If all the nine users respond positively to each question as a value or characteristic of the EL method, the overall value will be  $(9 \times 10 = 90)$  points. The value or weight of question number 3 is considered as zero when it is positive. Therefore only ten questions are considered to get the overall value of the method. So, the actual value for the EL method among the nine users is about  $(44/90 = 49\%)$  of the maximum expected weight.

#### **4.4.7.4.7 The Profitability Index (PI) Method**

The Profitability Index (PI) is the ratio of the net cash flow to the amount of money invested to buy the equipment. This method is normally used to rank the replacement alternatives.

#### **PI Characteristics and Effectiveness**

Since none of the participants uses the PI method, the effectiveness will be determined based on the literatures review.

1. **Simplicity:** The PI is not complicated method.
2. **Input Data Available:** The required input data to the PI are the expenses, revenues, investment period, and the interest rate. The revenues and expenses are the variables that need to be equated. Inputs to estimate these revenues and expenses are needed from the manufacturer and the company that will be using the equipment. The cash flow formula is used to regulate these expenses and revenues and discount them based on the time value of money, the interest rate, and the investment period. The interest rate and the investment

period are usually estimated by the company based on their financial and planning objectives.

3. **Require Excessive Knowledge of Accounting:** The PI method does not require excessive knowledge of accounting since all the required information are pre-defined and formulas are available for the calculations.
4. **Guideline Range is Available:** Since the calculation formulas are pre-defined, only the interest rate and the investment period need guidelines. The interest rate and the investment period normally follow the predefined company's guideline ranges and values.
5. **Measures the Future Risk Period:** The PI depends on the investment period and does not indicate or measure the future risk period.
6. **Measure the Rate of Return:** The PI method does not measure the rate of return.
7. **Measures the Worth of the Bid:** There are no indications on the method to the worth of the bid.
8. **Consider the Time Value of Money:** Actually the method consider the time value of money through the interest rate that need to be estimated as an input data. The selected interest rate does consider the time value of money.
9. **Consider the Expected Salvage Value:** The PI method does not consider the salvage value.
10. **Consider the Obsolescence and Deterioration:** The method does not consider obsolescence or deterioration of the equipment.
11. **Determine the Expected Economic Life:** The PI method does not determine the expected economic life of the equipment.

The PI considers only the associated costs and does not pay any attention to the revenues that might be gained from the equipment utilization. That might be one of the drawbacks that reduce the use of the method.

The input data from the participants on the effectiveness of each financial evaluation method were plotted on Figure 4.1. It can be noted that the EL method has the highest number of users & the highest number of points and therefore can be considered the most commonly used method for evaluating the equipment replacement proposals.

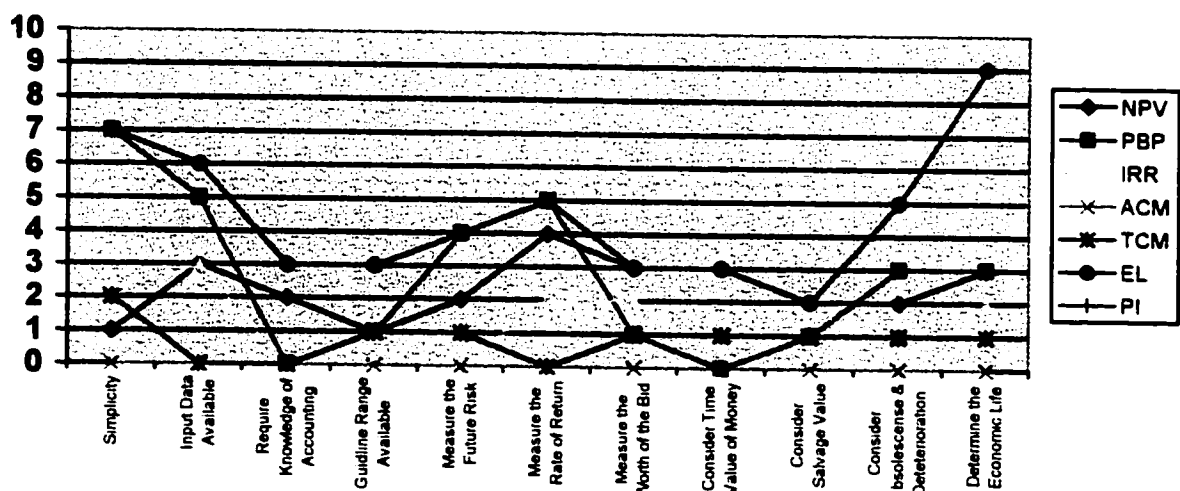


Figure 4.1 Financial Evaluation Methods Effectiveness

#### 4.4.7.5 Using Software Programs for Replacement Analysis

Computers are nowadays used in almost every field. Software programmers are always looking for ways to reduce the time, resources, and cost of doing routine and mathematics activities that can be taken care of by software programs. Software programs also help in ensuring accurate and

right calculations. Nowadays codes and programs can be written for replacement models and those facilitate and reduce the time and effort in performing the replacement analysis process. Table 4.31 presents the distribution of the extent of software usage among the participants. It is found that only two companies are using software programs on the replacement analysis. These two companies are grade three and that clearly indicate that our companies are still behind in utilizing computers and computer programs technology in improving their performance and optimizing the resources. This might be due to the less frequency of changing the equipment that reduces the need for better and precise ways of replacement analysis. It might be also due to the unavailability of good software models that are proven to be good to use for these type of analysis.

<b>Use Software?</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Yes	2	9.52	2	9.52
2. No	18	85.71	18	95.23
3. No Response	1	4.77	21	100.00

**Table 4.31 Use of Software in the Replacement Analysis**

Some of the software programs used in the field of equipment replacement analysis are Novell NetWare DOS, Excel based, and Access based analysis programs.

#### **4.4.8 Policy Regarding New Equipment Models**

Equipment manufacturers introduce new equipment models into the market from time to time. When a firm is using a piece of equipment and it finds that there is newer and better equipment available in the market, the firm wants to acquire it. But there are many constraints on the firm. So, the firms establish a policy regarding the new equipment that appears to be superior to the

ones they are using. Table 4.32 presents the frequency distribution of the policies regarding new equipment in the market. About 52 percent of the participants seem to buy new models to replace inefficient equipment. Five participants like to test new models by renting before buying them while two like to wait until the equipment become familiar and bugs are known to avoid any risk in using the equipment. Hence the popular practice among the contractors is to buy new equipment models only when they need to replace inefficient existing equipment. They buy whatever they find in the market, which caters to their needs, based on the expected performance and price of the equipment. The reason for the tendency of buying new equipment to replace inefficient one might be due to the high money value of the equipment which is a considerable asset to the contractor and force him to carefully evaluate any related change in order to avoid any possible losses.

<b>Policy?</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Buy Immediately	0	0	0	0
2. Buy to Replace Inefficient Equipment	11	52.38	11	52.38
3. Test by Renting Before Buying	5	23.81	16	76.19
4. Wait Till Bugs are Known	2	9.52	18	85.71
5. No Response	3	14.29	21	100.00

**Table 4.32 Policy Regarding New Equipment Models**

This seems to be a good practice, because a user cannot be expected to dispose off his old equipment and buy new one whenever new equipment is launched in the market. However, the testing of the new equipment by renting is also a good method, for checking out the promises of the manufacturer, and to ascertain whether the newer equipment is really better one.

#### 4.5 Equipment Financing

After the decision is made to acquire particular equipment, some kind of financing has to be arranged for the acquisition. Table 4.33 illustrates the frequency of usage of the different Methods of financing. There are different types of financing. The majority of the participants prefer to make outright purchases by using cash from retained earnings. This method of financing for acquisition of equipment is the cheapest. Hence, this is the most popular method of financing. The next popular type of financing is to use trade credit to finance their equipment. Trade credits enable the contractor to get the equipment financed by the dealer. The other popular methods are to take bank loans; either short or long terms depending on the contractor financial capability and the interest rate.

All the participants regardless of their grades try to make outright purchases for acquiring their equipment. While they use the short or long term loans also for acquiring, they use it to a smaller extent. This practice is observed regardless of the participants having written policies. Outright purchases help a user to buy the equipment at least possible price. Hence, to maximize the profits, the contractors might tend to buy equipment by making outright purchases.

<b>Financing Method</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Outright Purchase	16	76.20	16	76.20
2. Short term bank loan	1	4.76	17	80.96
3. Long term bank loan	1	4.76	18	85.72
4. Service lease	0	0	18	85.72
5. Trade credit	2	9.52	20	95.24
6. No response	1	4.76	21	100.00

Table 4.33 Type of Financing

## **4.6 Equipment Economics**

This section of the equipment policy concerns with the economic evaluation of the equipment during the life of the equipment. Long-range plans are prepared for the economic utilization of equipment. The economic working life of the equipment is determined by conducting economic analysis and this helps in replacing the equipment at the end of this life. Equipment is also continuously depreciated during its life. The deferent methods of depreciation are discussed here. The comparison for cash flows of the equipment is calculated to determine the profiles from the usage. All these factors are discussed in the following sections.

### **4.6.1 Capital Budgeting**

In order to plan for investing large amounts of capital in equipment, the contractors prepare long-range capital budgets. These budgets are prepared to keep the top management informed about the economic status of the firm. The budgets dictate how much capital could be invested in equipment in a given period of time. Standard forms are used for capital budgeting and appropriation requests.

#### **Types of Budgeting Plans**

Plans are two types; long range plans, which cover the budget for a long period of time, and short-range plans. It has been found that three-fourth of the participants formally prepare a long range capital budgeting. Even though the number of participants who did not prepare a formal budget is low (less than 25%), it indicates that some of the firms do not have long-range plans. Such companies tend to work on a project-to-project basis. Thus as a result of not having a long range plan, such firms generally run into trouble whenever a crisis occurs, since they are not well

prepared to solve it. This not only makes equipment management difficult but also creates trouble in the general management of the firm.

<b>Budgets Prepared?</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Yes	15	71.43	15	71.43
2. No	5	23.81	20	95.24
3. No response	1	4.76	21	100.00

**Table 4.34 Capital Budgeting**

### **Use of Standard Forms**

Table 4.35 shows the extent of usage of standard forms for capital budgeting. The participants who formally prepare long-range capital budgets use standard forms for capital budgeting and appropriation requests. These forms are either published by government ministries, or by standard publications, or they are designed in-house for specific needs and purposes.

<b>Is Forms Used?</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Yes	14	66.67	14	66.67
2. No	6	28.57	20	95.24
3. No response	1	4.76	21	100.00

**Table 4.35 Usage of Standard Forms**

Standard forms used by firms of all the grades. Three quarters of the participants are using standard forms for capital and budgeting and appropriation.



## **4.7 Equipment Operation and Maintenance**

Equipment should be operated and maintained properly so that it gives the most of its economic value to the owners. This section is concerned with the realization of the profits from the operation of the equipment.

### **4.7.1 Equipment Operation**

Equipment is acquired to perform desired activities. During their operation, policies are set to regulate their performance for keeping them in excellent shape and to prolong their economic life. One of the strategies is to assign equipment to an operator who will be responsible for it. This does not mean a single operator who will be a single point of failure in case the company loses him or something happen to him. Hence, multiple operators can be assigned to the same type of equipment but each one to be responsible for one equipment.

Another important strategy is to have good training programs for the operators to develop good background and knowledge about the equipment. This will help to report and clarify the problems that might occur during operation of the equipment to maintenance.

### **4.7.2 Equipment Maintenance**

Maintenance is the continuous upkeep of equipment in order to keep it in working condition. There are three major types of maintenance; routine, preventive, and overhauls.

Some of these maintenance tasks might not be done at the contractor facilities depending on the capabilities and manpower that are on hand. Table 4.36 shows the types of maintenance that the participants perform in-house.

<b>Maintenance Level</b>	<b>Frequency</b>	<b>Percent</b>
1. Lubrication & filter change	8	38.10
2. All repair jobs	19	90.48
3. Overhauls	5	23.81

**Table 4.36 In-House Maintenance Level**

About 40% of the participants perform the routine maintenance in-house and about 90% perform all the repairs in-house. This indicates that most of the participants have maintenance facilities and personnel who normally do all the routine and preventive maintenance checks in-house. Only quarter of the participants have facilities to and perform the overhauls in-house.

Maintenance is performed periodically on all the participants, but the period differs from participant to another depending on his workload and the proximate of the equipment to the workshops. Some of the participants said they also perform maintenance whenever the machine needs it. A couple of the participants said that they perform maintenance during their slack work periods. This practice of performing maintenance leads to losses to the firm due to unavailability of machines if they break down during work.

### **Routine Maintenance**

Routine maintenance is maintenance of a minor nature and is performed more frequently. It includes lubrication and filters change, tires change, and minor repair. This is normally does not require specialized technician and does not require pulling the equipment out of the project for maintenance.

## **Preventive Maintenance**

Preventive maintenance is routine checks that are regularly scheduled for an equipment to ensure the readiness and effectiveness of the equipment and to predict the sources of failure on that equipment before the failure.

<b>Do You Have Scheduled Preventive Maintenance</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Yes	18	85.71	18	85.71
2. No	3	14.29	21	100.00

Table 4.37 Contractors Having Preventive Maintenance

Table 4.37 indicates that most of the participants have scheduled preventive maintenance programs and the schedule of these maintenance programs varies as shown in Table 4.38. about two third of the participants conduct the preventive maintenance annually while the other third schedule it to be every two years.

<b>How Often You Conduct Preventive Maintenance</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Annually	14	66.67	14	66.67
2. Every two years	7	33.33	21	100.00

Table 4.38 Conducting Preventive Maintenance

## **Overhauls**

Overhauls are major repairs of equipment . such repairs are very costly and consume a lot of time. Such repairs undertaken when the machine's productivity falls very low, and it becomes

uneconomical to operate them. If the productivity can be restored by running a complete check or by replacing some parts, then overhauls are undertaken.

<b>Do You Have Scheduled Overhauls Programs</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Yes	10	47.61	10	47.61
2. No	8	38.10	18	85.71
3. No Response	3	14.29	21	100.00

**Table 4.39 Contractors Having Overhauls Programs**

Only 50% of the participants have scheduled overhauls for their construction equipment while the majority of the contractors try to avoid that as shown in Table 4.39.

<b>How Often You Conduct Overhauls Programs</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Annually	5	23.81	5	23.81
2. Every two years	2	9.52	7	33.33
3. Every five years	5	23.81	12	57.14
4. No Response	9	42.86	21	100.00

**Table 4.40 Conducting Overhaul Programs**

Table 4.40 indicates that overhauls have different schedule from participant to another. About a quarter perform it every year and another quarter every five years. Others have various schedules.

### **4.7.3 Equipment Records**

Records are kept on the utilization, maintenance and operation of the equipment. Equipment records are used for various purposes such as to calculate the productivity, cost of production, to

allocate costs to specific jobs, and to keep a tab on the condition and maintenance of the equipment.

There are many types of records that are normally maintained for construction equipment and the extent of the use depends on the firm's organizational rules and the utilization of these records. These records could be classified into cost and maintenance records. The maintenance record is a history file that is kept with the maintenance group and includes the repair details and all the other maintenance jobs that are done on the equipment. On the other hand, the cost record is also a history file for the equipment but it includes details of the costs of all the maintenance and repairs that were done for that piece of equipment. These are in the forms of reports and invoices. Table 4.41 lists the commonly used types of cost records.

<b>Equipment Cost Records</b>	<b>Frequency</b>	<b>Percent</b>
1. Operating hours	14	66.67
2. Repair costs	18	85.71
3. Overhauls costs	13	61.91
4. Operating expenses	14	66.67

Table 4.41 Equipment Cost Records

These commonly used costs records are; the operating hours, repair costs, overhauls costs, and operating expense records. The operating hours records are periodic reports that are filled by the operation personnel to indicate how long the equipment was utilized for that job or project or during that period of time. The operating hours record helps in determining how much is the equipment being utilized and how far is it from the end of the economic life. About 14 participants collect this type of records. The repair costs records are cost reports or invoice for

the routine and preventive maintenance that were done on each equipment. About 18 of the participants collect these types of records. The overhauls costs records are also costs and invoices reports about the overhauls that were conducted on a piece of equipment. About 13 of the participants collect this type of records. The operating expense records are reports about the costs of fuel and transportation. It sometime includes the oil and filter change costs. About 14 of the participants collect this type of records.

The collection period for these cost type records vary from one participant to another depending on the need for that type of record or report and the organizational rules of the firm regarding that issue. Table 4.42 shows that the participants collect these record daily, weekly, monthly, or job wise. About 38% of the participants collect these records monthly. This does not mean they generate these reports monthly. Hence, the reports are always their and they gets filled whenever the job is done or as set by the organization rules.

<b>Cost Records Collection Period</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Daily	5	23.81	5	23.81
2. Weekly	3	14.29	8	38.10
3. Monthly	8	38.09	16	76.19
4. Job-wise	2	9.52	18	85.71
5. No Response	3	14.29	21	100.00

**Table 4.42 Cost Records Collection Period**

The equipment management policy delegates the responsibility of keeping equipment utilization records to the personnel in the firm. Table 4.43 shows the distribution of the level of gathering data. It has been found that half of the participants have the job superintendent to gather the

equipment records. Also about have of the participants have the foreman to gather the records. Only one participant has the mechanic to gather the records.

<b>Cost Records Gathering Level</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Job superintendent	8	38.10	8	38.10
2. Foreman	9	42.85	17	80.95
3. Operator	0	0	0	80.95
4. Mechanic	1	4.76	18	85.71
5. No Response	3	14.29	21	100.00

Table 4.43 Cost Records Gathering Level

As mentioned before in this section, the cost records can help in predicting the economic life of the equipment and how much is being spent on that equipment in order to have a feeling when that equipment need to be replaced. Also, this helps to compare the decision to continue using the current equipment with the decision of replacing it with new one. Table 4.44 indicates that two-thirds of the participants utilize the cost records in the replacement evaluation and decision.

<b>Using Cost Records In Replacement Decision</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Yes	12	57.14	12	57.14
2. No	6	28.57	18	85.71
3. No Response	3	14.29	21	100.00

Table 4.44 Using Cost Records in Replacement Decision

Another use for the cost records is the production-time-cost reports generation. These are periodic reports that compare the production of the equipment with its cost. This gives the

management a feeling about how much is the equipment being utilized. This also could be used to suggest areas of improvement and deficiencies that need to be tackled. Table 4.45 shows how often the production-time-cost reports are generated. The preferable period among the participants is to generate these reports monthly or when the job requires them.

<b>Production-time-cost Records Generation</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Not produced at all	1	4.76	1	4.76
2. Daily	3	14.29	4	19.05
3. Weekly	2	9.52	6	28.57
4. Monthly	7	33.33	13	61.90
5. Job-wise	5	23.81	18	85.71
6. No Response	3	14.29	21	100.00

Table 4.45 Production-time-cost Records Generation

Nowadays computers can be used to facilitate gathering the cost records, to create standard forms for each type of records, and to manipulate the data and generate reports. Table 4.46 shows that almost all the contractors uses computers to manipulate the cost records.

<b>Using Computers to Manipulate Cost Records</b>	<b>Frequency</b>	<b>Percent</b>	<b>Cumulative Frequency</b>	<b>Cumulative Percent</b>
1. Yes	18	85.72	18	85.72
2. No	1	4.76	19	90.48
3. No Response	2	9.52	21	100.00

Table 4.46 Using Computers to Manipulate Cost Records



#### **4.8 Comparison of Policies: Benchmarking**

The policies of the contractors from Saudi Arabia are compared with the policies of contractors from USA. The process of comparison is called benchmarking.

##### **4.8.1 The Concept of Benchmarking**

Benchmarking is a process of comparing the performance and process of an organization with similar organizations in order to identify areas of improvement and to measure the performance.

Benchmarking uses different tools for the comparison of performances and processes. These may be statistical tools or other tools, which enable the firms to quantify the performance or the process. The data for this quantification is collected through a survey of the processes. This data is then quantified in a manner, which enables the firms to interpret and compare those processes.

The tool for data collection in the present research is a questionnaire. This questionnaire collects data regarding the equipment management policies in Saudi Arabia. The data is quantified to enable the comparison with similar data on the practices in the USA. The data on the practices in the USA is taken from some of the research papers published in the USA in the past few years. These research papers include “Equipment policy of top 400 contractors: a survey” by Tavakoli et. Al and “Contractor equipment management practices” by Shexnayder and Hancher. These researchers had conducted a similar research in the USA.

A statistical comparison is made between the practices of the two countries. Some of the basic statistics in the form of percentages are compared by drawing up bar charts. This enables a quick comparison of the different factors involved.

The research tries to present a framework for the benchmarking the practices of both countries. The research follows the conceptual approach of benchmarking for comparing the equipment management practices between the two countries. The current research does not compare the best

practices among the contractors of the two countries. This research only compares the popular practices of both countries in the field of equipment management and replacement. These practices may not be the best in their field. The best practices in the field have to be decided by the contractors themselves. They can do this by setting some standards. The practices have to be quantified in a measurable form to set the standards. These standards may involve improvement or achievement of financial standards, quality standards, productivity standards, and safety standards.

The comparison between the findings of the present survey and the findings from some of the surveys conducted in the USA are discussed below. Since, some of the questions for the survey were taken from the above-mentioned surveys, some of the questions had similar answers. These answers provide the data for comparison.

#### **4.8.2 Characteristics of the Contractors**

This section includes comparison of the types of work undertaken and the extent of the equipment ownership among the contractors of the two countries.

##### **4.8.2.1 Type of Work**

The percentage of involvement in the various types of construction is given in the Table 4.47 below. As can be seen from the table and the following bar chart, the most popular type of construction in both countries is building. This is due to the continuous residential growth of the cities and the growth of the housing associated to industrial facilities. The involvement in industrial construction in the USA is much more than Saudi. This is due to the early start of the industrial growth in the states compared with late start in Saudi.

Types of Construction	Saudi (%)	USA (%)
1. Buildings	57.14	59
2. Roads	33.33	22
3. Industrial	28.57	56

Table 4.47 Types of Construction

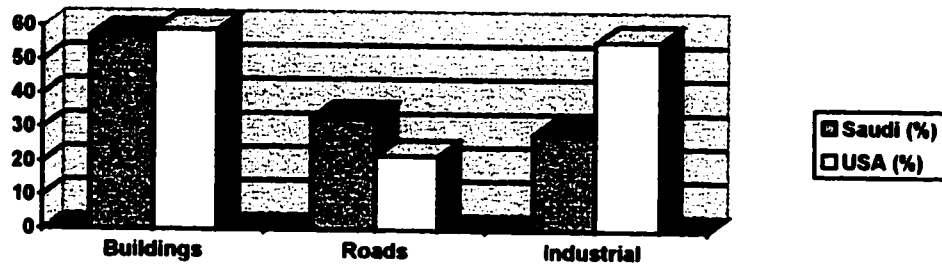


Figure 4.2 Types of Construction

#### 4.8.2.2 Annual Work Volume

The annual work volume of the two countries is shown below in Table 4.48. Due to the large work volume in the USA, it cannot be precisely compared with the one for Saudi and both are indicated in the table below to show how much is the difference between the two work volumes.

Annual Work Volume	Saudi (%)	Annual Work Volume	USA (%)
1. 1-100 Million SR	66.67	1. Up to 50 Million \$	27.4
2. 100-200 Million SR	14.29	2. 50-100 Million \$	36.9
3. 200-500 Million SR	14.29	3. 100-200 Million \$	14.7
		4. 200-500 Million \$	14.7
		5. Over 500 Million \$	6.3

Table 4.48 Annual Work Volume

#### 4.8.2.3 Extent of Equipment Ownership

The extent of ownership is shown in Table 4.49 and the associated bar chart below. Both countries construction contractors have a high ownership rate. The ownership rate of Saudi Arabia contractors is higher than the one for the USA contractors. The reason for this may be the difference states and conditions of lease and rental markets in both countries. The lease market in US is far more experienced and advanced than in Saudi Arabia. As such, the lease market is much more developed in the USA than in Saudi Arabia. Hence usage of equipment by leasing is more popular in the US than in Saudi Arabia. The users in Saudi Arabia tend to buy most of the equipment they intend to use. Renting only specialized equipment, or in the case of breakdowns.

	Saudi (%)	USA (%)
% Of Ownership	83.29	68.7

Table 4.49 Percentage of Ownership

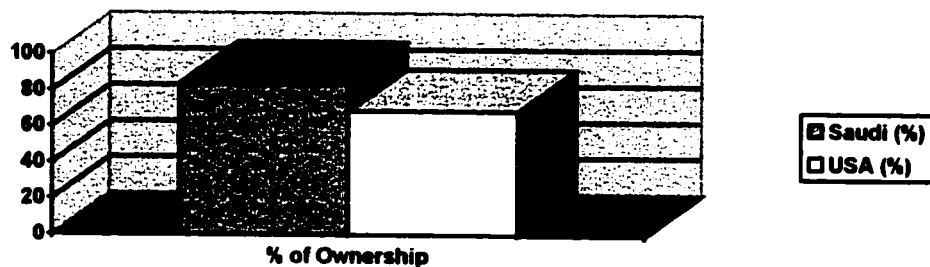


Figure 4.3 Percentage of Ownership

### 4.8.3 Equipment Replacement Policy

Since the available surveys from the states do not have information about the equipment replacement manual or its content, benchmarking cannot be done for the policy manual. However, most of the equipment replacement elements and methods discussed in this research were covered in the available surveys from the states.

#### 4.8.3.1 Replacement and Acquisition Need Initiation

The contractors from the US stress the importance of replacing insufficient equipment and replacing when the financial picture is good. This seems to be the same pattern that Saudi Arabia contractors tend to do in addition to conducting feasibility studies to evaluate the need for the replacement. Table 4.50 and the associated bar chart below illustrate these patterns.

When to Replace Equipment	Saudi (%)	USA (%)
1. After Economic Study	38.10	8
2. Inefficient Equipment	85.71	54
3. Before a New Job/Overhaul	19.05	8
4. When Equipment is Obsolete	23.81	7
5. Good Financial Picture	33.33	22

Table 4.50 When to Replace Equipment

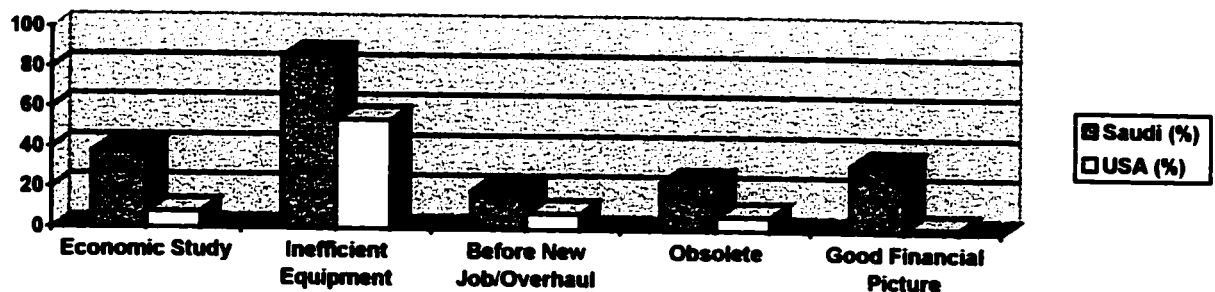


Figure 4.4 When to Replace Equipment

#### 4.8.3.2 Optimum Replacement Time

The most popular method to determine the optimum replacement time for a piece of equipment among the contractors of both countries is to replace when the cost of repairs gets higher than the profits accrued from it. The contractors from both countries also use the determination of a reasonable economic life for the equipment to decide on the replacement time. Normally the equipment manufacturer provides an operating curve for the equipment expected life under certain required operating and maintenance conditions. This curve is used by the contractors to decide on the economic life of the machine.

Optimum Replacement Time	Saudi (%)	USA (%)
1. Generation of a Cost Curve	4.76	9.4
2. When High Repairs Cost	76.19	74.1
3. Determination of Economic Life	14.29	37.6

Table 4.51 Optimum Replacement Time

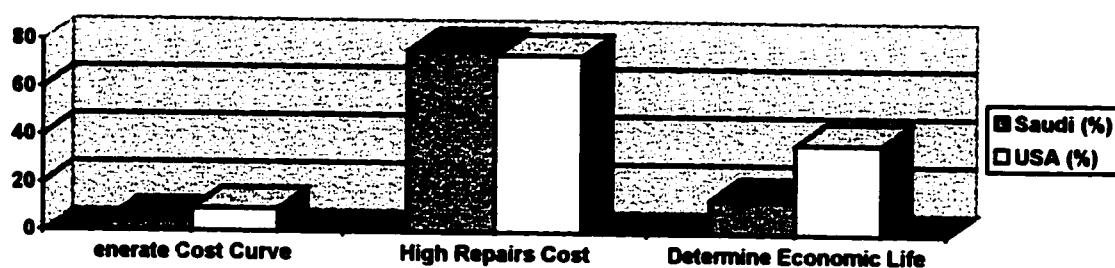


Figure 4.5 Optimum Replacement Time

#### 4.8.3.3 Frequency of Replacement

The contractors from both countries generally agree to the policy of replacement. The contractors differ in their opinion about changing equipment during different levels of competition. The

contractors from Saudi Arabia tend to replace equipment when there is high competition, whereas the contractors from the US tend to replace equipment when there is low competition.

Equipment Replacement Frequency	Saudi (%)	USA (%)
1. High Competition	61.91	4
2. Low Competition	9.52	20
3. No Change	19.05	76

Table 4.52 Equipment Replacement Frequency

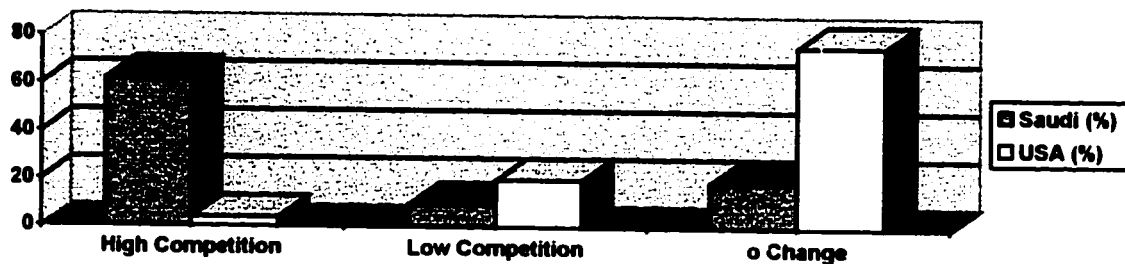


Figure 4.6 Equipment Replacement Frequency

#### 4.8.3.4 Responsibility for Final Decision

The top management in Saudi Arabia tends to have more say in the final decision regarding equipment acquisition and disposal from the US. Similarly, the project and equipment managers are given more responsibility in the US than in Saudi Arabia. This indicates that the responsibility in the US is more de-centralized than in Saudi Arabia. That might be due to the tend of the Saudi contractors top management to put more control and involvement than in the states where the top management follow the management hierarchy rules and give more responsibility to their lower management.

<b>Final Decision Responsibility</b>	<b>Saudi (%)</b>	<b>USA (%)</b>
1. President (CEO)	71.43	65.9
2. Board of Directors	14.29	9.9
3. Project Manager	4.76	11
4. Equipment Manager	4.76	35.2

Table 4.53 Final Decision Responsibility

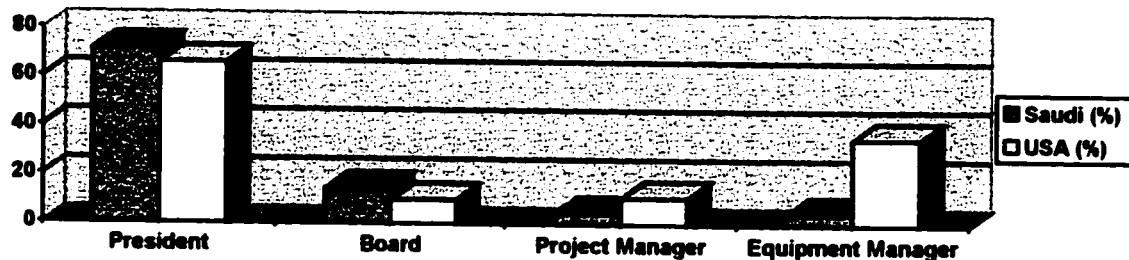


Figure 4.7 Final Decision Responsibility

#### 4.8.3.5 Identification of Replacement Alternatives

The percentage of contractors who search and consider alternative investment proposals is high in both countries with the contractors in the US ahead. This might be due to the availability of more sources of information that can help to do more search for better alternatives. It could be also due to the higher competition in the US between the equipment manufacturer and their tends to keep the contractors updated with the latest technologies.

<b>Are Alternatives Searched?</b>	<b>Saudi (%)</b>	<b>USA (%)</b>
1. Yes	57.15	87.8
2. No	33.33	12.2
3. No Response	9.52	

Table 4.54 Search for Replacement Alternatives



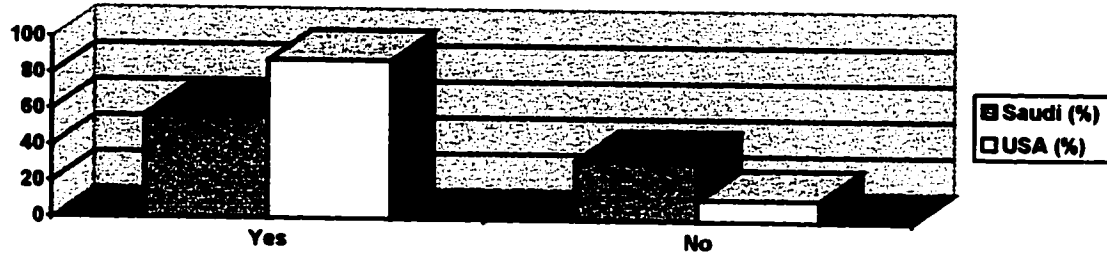


Figure 4.8 Search for Replacement Alternatives

#### 4.8.3.5 Quantitative Factors Studied in the Replacement Analysis

The table below indicates that the US and Saudi Arabia contractors put their highest consideration on the downtime cost of the equipment and the depreciation rate. The downtime cost is an indication of how critical is the equipment to the current project and the US contractors pay their highest consideration to this factor in order to avoid any slippage to their project schedule. The depreciation rate is an indication to the equipment efficiency and productivity and the US contractors pay also high attention to this factor in their replacement evaluation in order to ensure that the equipment is very efficient and suitable for the job. In addition to the downtime cost and the depreciation rate, the Saudi contractors puts high consideration to the equipment obsolesce while the US contractors do not consider this as a major factor. This indicate that the Saudi contractors tends to avoid the problem of unavailable proper equipment replacement or some spare parts in Saudi incase an equipment fail or need major overhaul. The Saudi contractors give moderate consideration to the time value of money and the resale value of the equipment while the US contractors do not do not see these two factors as major factors.

Quantitative Replacement Factors?	Saudi (%)	USA (%)
1. Inflation	48	47
2. Escalation	53	N/A
3. Downtime Cost	89	71.1
4. Obsolescence	82	36.1
5. Depreciation	76	68.7
6. Time Value of Money	67	59
7. Salvage Value	62	N/A
8. Taxes	N/A	47

Table 4.55 Quantitative Replacement Factors

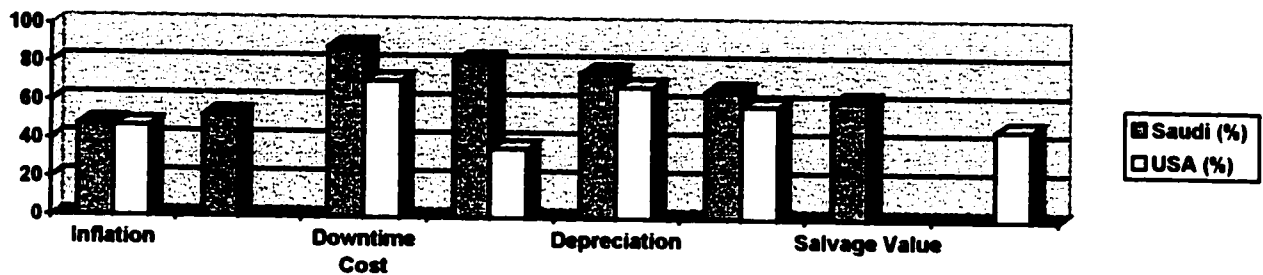


Figure 4.9 Quantitative Replacement Factors

#### 4.8.3.6 Depreciation Accounting Method

The contractors in the US tend to use the straight-line method or the double declining balance method only to calculate the depreciation. The double declining balance method is used widely in the US as it facilitates fast depreciation of their assets. The fast depreciation of assets helps the contractors to save some money in Texas. This may not be so widely used in Saudi because of the low taxes. The Saudi contractors tend to use the straight-line method and the percent of life methods most of the time due to the simplicity of the two methods.

<b>Depreciation Accounting Method</b>	<b>Saudi (%)</b>	<b>USA (%)</b>
1. Straight Line Method	52.38	44
2. Double Decline Balance	4.76	56
3. Sum of Years Digit	4.76	0
4. Percent of Life	38.10	0

Table 4.56 Depreciation Accounting Method

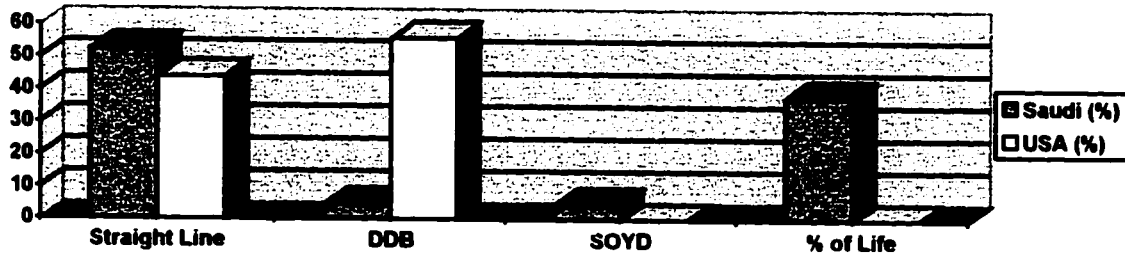


Figure 4.10 Depreciation Accounting Method

#### 4.8.3.7 Equipment Disposition Method

It can be seen from the table below that the contractors in the US tend to trade their used equipment back to the dealer more than their counterparts from Saudi. The low dependency of the Saudi contractors on this method might be due to the high cost of sending the equipment through the dealer back to the manufacturer for re-use. The auction sale is more popular among the contractors from Saudi than the contractors from the US. This might be due to the high initial cost of the equipment and the tendency of the small contractors to buy used equipment, which raise the disposition cost of equipment to attractive trends to the owners.

<b>Method of Disposition</b>	<b>Saudi (%)</b>	<b>USA (%)</b>
1. Trade to Dealer	4.76	61.6
2. Auction Sale	66.67	25.6
3. Sell to Others	28.57	82.6

Table 4.57 Method of Disposition



Figure 4.11 Method of Disposition

#### 4.8.3.8 Comparison of Quantitative Evaluation

There is a common practice in both countries regarding the comparison done in the quantitative evaluation of equipment investment proposals. The contractors from both countries tend to do detailed net cash flow analysis during the equipment replacement analysis. The contractors from both countries follow the same practice with the contractors from the US slightly ahead of those from Saudi Arabia.

Comparison of Quantitative Evaluation	Saudi (%)	USA (%)
1. Disbursements	19.05	34.3
2. Net Cash Flow	33.33	75.7

Table 4.58 Comparison of Quantitative Evaluation

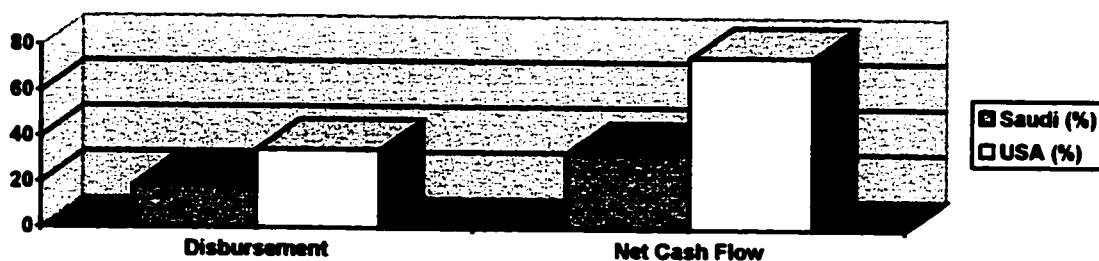


Figure 4.12 Comparison of Quantitative Evaluation

#### 4.8.3.9 Quantitative Evaluation Method

The surveys from the US indicate that the accounting return on the investment has the highest weight on the equipment replacement decision. The pay back period is considered as the second major figure that is considered in making the replacement decision in the US. The Saudi contractors consider the economic life as the highest considered figure. This might be due to the availability of measurable figures for the equipment life that is normally provided by the equipment manufacturer. The pay back period and the net present value have the second highest weight in consideration during the evaluation of the equipment replacement proposals in Saudi Arabia.

Quantitative Evaluation Method	Saudi (%)	USA (%)
1. Accounting Return	N/A	60.9
2. Pay-back Period	30	43.5
3. Net Present Value	26	12
4. Internal Rate of Return	15	28.3
5. Annual Cost	N/A	N/A
6. Total Cost	9	N/A
7. Economic Life	50	N/A
8. Profitability Index	N/A	N/A

Table 4.59 Quantitative Evaluation Method

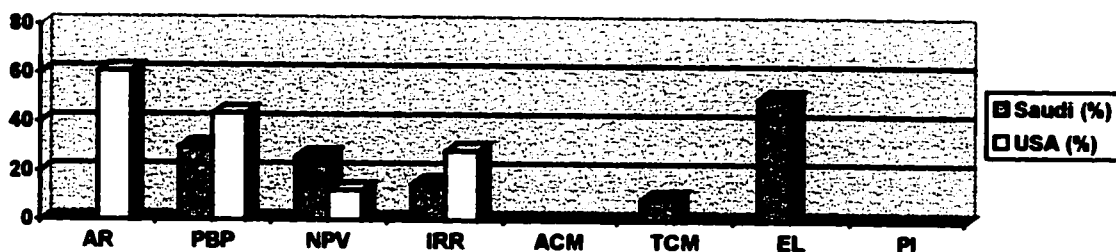


Figure 4.13 Quantitative Evaluation Method

#### 4.8.3.10 Determination of Minimum Rate of Return

The contractors in the US gave approximately equal weight to the use of the methods listed in the following table to determine the minimum attractive rate of return with the exception of the weighted cost method that is not popular to use. The contractors in Saudi tend to use the management-determined rate of return as a minimum most of the time. They also use the firm's determined rates that normally result from the historical records of the firm to determine the minimum attractive rate of return.

Minimum Rate of Return	Saudi (%)	USA (%)
1. Cost of Funds	9.52	26.6
2. Weighted Cost	9.52	11.4
3. Management Rate	42.86	32.9
4. Firms Rate	28.58	39.2

Table 4.60 Minimum Rate of Return

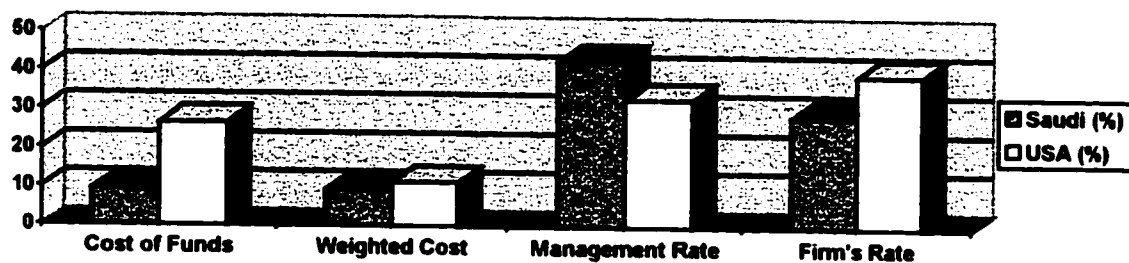


Figure 4.14 Minimum Rate of Return

#### 4.8.3.11 Receipt of Proposals

The surveys results below indicate the both countries contractors tend to calculate their internal rate of proposals values based on the collected information on the proposals. The contractors in

the US use to some extent the other methods, direct, dealers, and government rates to determine the proposals worth. The Saudi contractors tend to allocate some rates for the proposals if they don't have enough information.

<b>Determination of Proposals Receipt</b>	<b>Saudi (%)</b>	<b>USA (%)</b>
1. Directly allocate Revenues	28.57	36.8
2. Use Dealers Rental Rates	9.52	32.4
3. Use Government Rental rates	9	29.4
4. Calculate Internal Rates	57.15	57.4

Table 4.61 Determination of Proposals Receipt

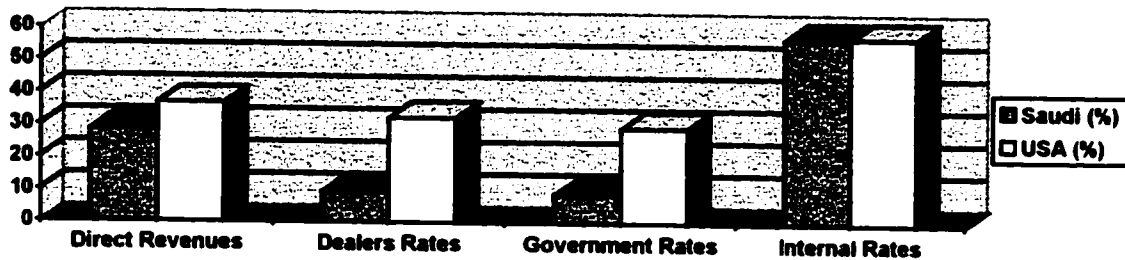


Figure 4.15 Determination of Proposals Receipt

#### 4.8.4 Policy Regarding New Models

The contractors from the US tend to test new equipment by renting or wait till bugs on the new equipment are known. The contractors from Saudi Arabia tend to buy new equipment mostly to replace inefficient existing equipment.

Policy Regarding New Models	Saudi (%)	USA (%)
1. Buy Immediately	0	2.4
2. Buy to Replace Inefficient Equipment	52.38	0
3. Test by Renting Before Buying	23.81	67.9
4. Wait Till Bugs Show	9.52	48.8

Table 4.62 Policy Regarding New Models

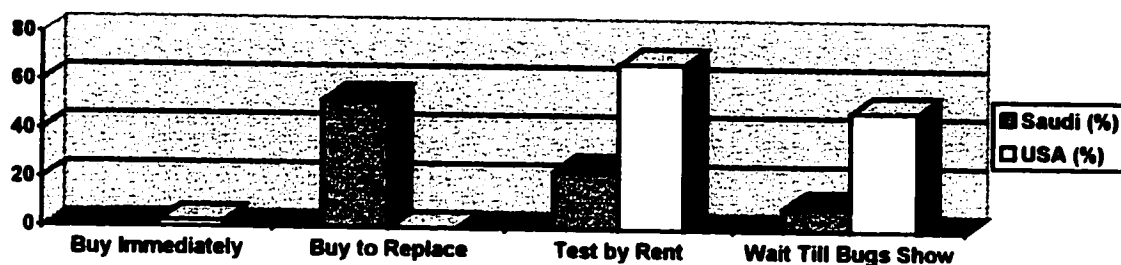


Figure 4.16 Policy Regarding New Models

#### 4.8.5 Equipment Financing

Outright purchase is the most popular method of financing new equipment in both countries. The short term, long term, and trade credit are also used in the US while their use in Saudi is not frequent.

Financing Methods	Saudi (%)	USA (%)
1. Outright Purchase	76.20	84.4
2. Short Term Loan	4.76	21.1
3. Long Term Loan	4.76	21.1
4. Service Lease	0	27.8
5. Trade Credit	9.52	4.4

Table 4.63 Types of Financing



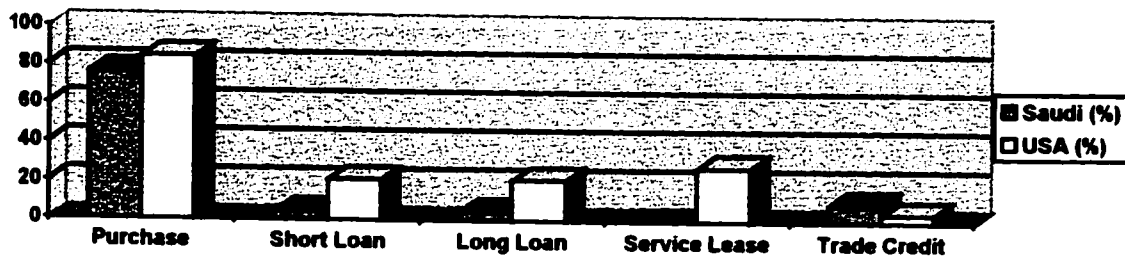


Figure 4.17 Types of Financing

#### 4.8.6 Equipment Operation and Maintenance

The contractors from both countries pay high attention and consideration to the equipment operation and maintenance and they collect and use their historical records in the analysis of the equipment replacement proposals. This clearly indicates that they realize how important these records are to the replacement decision.

##### 4.8.6.1 Maintenance Levels

The US contractors tend to do all the three levels of maintenance in-house with a tendency to do less unscheduled overhaul jobs in-house. The Saudi contractors tend to do up to the scheduled maintenance level in-house while other specialized firms normally do the unscheduled overhaul maintenance. This might be due to the number of equipment available with the contractors and the high cost of repairs that do not justify building more sophisticated shops to do these kinds of repairs.

Maintenance Levels	Saudi (%)	USA (%)
1. Preventive Maintenance	38.1	93.5
2. Scheduled Maintenance	90.48	85.7
3. Unscheduled Maintenance	23.81	63.6

Table 4.64 Maintenance Levels

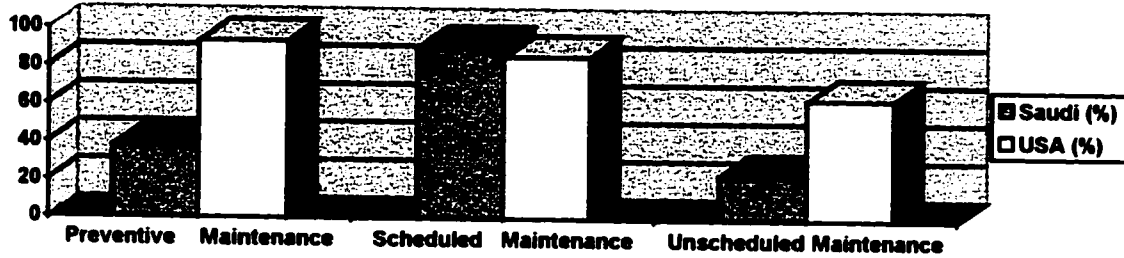


Figure 4.18 Maintenance Levels

#### 4.8.6.2 Type of Records Collected

The contractors from both countries tend to maintain all the types of records listed in the table below with the US contractors paying less attention to the overhaul costs and operating expenses. This might be due to the practice of returning or reselling the equipment to the dealers to these kind of jobs and they keep the details of the overhaul cost and material.

Records Types	Saudi (%)	USA (%)
1. Operating Hours	66.67	67
2. Repair Costs	85.71	56
3. Overhaul costs	61.91	39
4. Operating Expenses	66.67	39

Table 4.65 Records Types

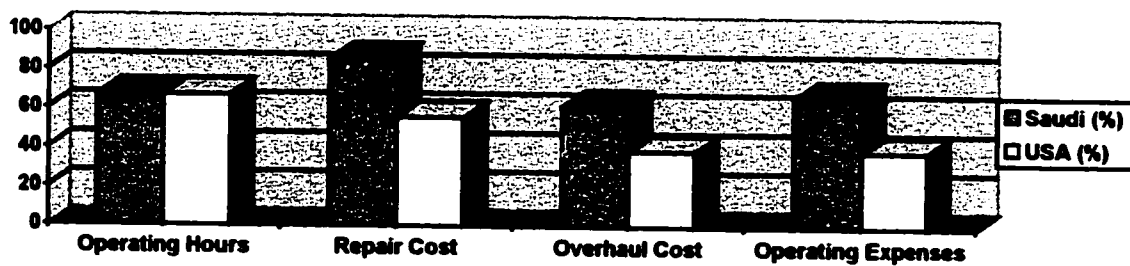


Figure 4.19 Records Types

#### 4.8.6.3 Who Gather the Records

The foreman in both countries keeps the cost records. The Saudi contractors tend also to keep the records with a higher level, the superintendent, which is a practice with the small companies.

Who Gather the Records	Saudi (%)	USA (%)
1. Superintendent	38.10	0
2. Foreman	42.85	69.1
3. Operator	0	27.3
4. Mechanic	4.76	18.2

Table 4.66 Who Gather the Records

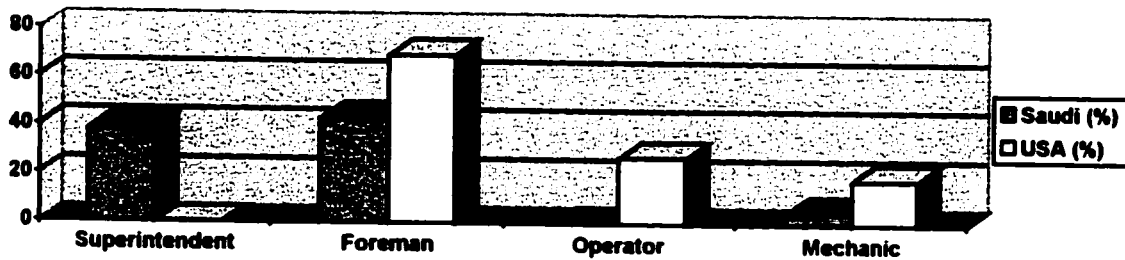


Figure 4.20 Who Gather the Records

#### 4.8.6.4 Equipment Records

The contractors from both countries are in agreement regarding the use of maintenance and operating cost records in making the replacement decisions with those from the US being slightly ahead in the frequency.

Use Equipment Records	Saudi (%)	USA (%)
1. Yes	57.14	78
2. No	28.57	5

Table 4.67 Using Equipment Records

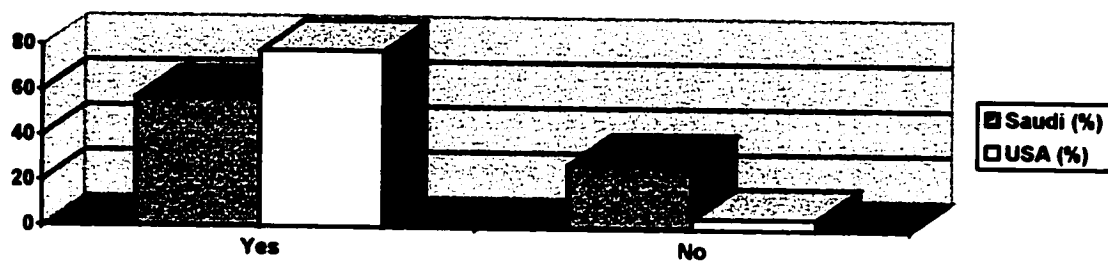


Figure 4.21 Using Equipment Records

## **CHAPTER 5**

### **SUMMARY AND CONCLUSIONS**

#### **5.1 Summary of the Study**

Equipment is a very important asset for a construction contractor. It also forms a substantial portion of the construction costs of any project. Hence, proper management, planning, and control of the construction equipment are important to the success of the contractor. Proper management includes monitoring the equipment productivity and cost reports in order measuring the efficiency of the equipment. Based on the efficiency evaluation and the contractor need for additional equipment, the contractor need to take the proper replacement decision either to keep the existing equipment, replace it, or add new additional equipment in order to cover the contractor shortages or needs for construction equipment.

On the other hand, proper planning and scheduling of the construction equipment can be through scheduling the proper job that suite the capabilities of the equipment, scheduling the right operator, and scheduling and conducting all the required maintenance and overhauls for the equipment.

The current research is an exploratory study of the equipment replacement practices of the contractors in Saudi Arabia. Data for the study was collected using a questionnaire distributed to the contractors in the Eastern Province of the Saudi Arabia. Contractors working in the areas of buildings, roads, water and sewage, electrical, mechanical, and industrial works were selected for the study. Out of a sample of 74 contractors, 21 responded to the study by filling and sending the questionnaire. This data was then coded and analyzed using the SAS software. The analysis produced frequency charts, cross-tabulation charts, and correlation charts. The policies of the

contractors were interpreted from the frequency charts. The elements of the policy were cross-tabulated against the grades of the contractors to see any variation in the policies. The elements of the policy were also tabulated to see whether having a documented policy made any differences in the management practices.

Then detailed typical equipment replacement policy was proposed and discussed in more details. That includes methods to find the proper replacement time for existing equipment and proposing the commonly used financial evaluation methods for the replacement proposals. The replacement methods characteristics and effectiveness were evaluated based on the contractor's responses to the questions on that regard.

## **5.2 Major Findings**

The following are some of the major findings of the study:

1. Contractors own more than 83% of the equipment they use, and lease equipment only in case of increased demand.
2. Only 19% of the participants have documented equipment replacement policy. The others follow a management policy but it is not documented.
3. Existing equipment is replaced when it becomes inefficient and the cost of maintenance is too high. The replacement is done at the end of the equipment economic life.
4. Equipment investment proposals are initiated by the equipment maintenance department and the final decision regarding acquisition or disposition is taken by the President (CEO) of the company.
5. Alternatives to major equipment investments (investments above SR 0.89 million) are specifically searched and evaluated.

6. The straight line method is the mostly used method to determine the depreciation cost in the value of the equipment.
7. The most commonly used disposition method is the auction sale.
8. The equipment is considered obsolete when the equipment economic life is exceeded. The annual obsolescence rate is about 10%.
9. Management determined rate of return is the commonly used method to dictate the minimum attractive rate of return from the investment alternative.
10. The economic life method is the most commonly financial evaluation method for the equipment replacement alternatives.
11. Only few contractors use software programs to help in conducting the analysis of the equipment replacement proposals.
12. The policy of most of the contractors toward the new equipment models is to buy only to replace inefficient equipment.
13. Outright purchase by using cash is the most popular method for procuring equipment. equipment is usually bought from dealers in the country.
14. The contractors prepare long range capital budgeting plans and use standard forms for capital budgeting.
15. Most of the contractors have scheduled preventive maintenance programs while only 50% have scheduled overhaul programs for their construction equipment.
16. The commonly periodic cost records include operating hours, repairs, overhauls, and operating expenses cost records. They are evaluated by the job superintendent.

### **5.3 Conclusions**

Although few contractors are found to have documented replacement policies, it is found that there is a uniform practice of management among all the contractors. This indicates that there is a policy for management although it is not properly documented. The fact that contractors claim a gain from the resale of their equipment indicates that the equipment is managed profitably. The main goal of any equipment replacement policy is to enable optimization of resources and maximization of profits.

Even though there is no written replacement policy for most of the contractors, the implementation of sound principles of management as well as the influence of experience leads to a profitable management of the equipment.

### **5.4 Recommendations**

In the light of the above discussion, it is recommended that the contractors adopt better replacement practices that will give them maximum returns on their investments in equipment. Such practices and regulations should be properly documented so as to communicate the company policies to the whole organization. It is recommended to the contractors who do not have a written policy manual to document their equipment management and replacement policies, to increase their profitability. Such policies should cover all the aspects related to the equipment acquisition, finance, replacement, maintenance, and operation. A proposed equipment replacement policy was given in this study and can be used to organize and properly conduct the replacement policy. It is also recommended that contractors extend the use of computers, software programs, and the Internet to improve their equipment replacement policies. It is also recommended that the contractors update their policies periodically, or whenever the need arise,



or whenever a better policy or approach found to be useful to adopt. The updates need to be well documented.

The authorities in the country, such as the Ministry of Industry, the Engineering Committee, the Contractors Committee, and other concerned authorities are recommended to promote, preach, and encourage contractors to develop, document, and follow their equipment management policies.

The academia are recommended to conduct further research and in-depth studies in the field of equipment management and replacement, formulate the best policies which will suit the work conditions in the country, and forward the results and recommendations of such research to the contractors who can benefit from the findings of such studies.

### **5.5 Future Studies**

This subject offers a lot of scope for future research. Some of the possible studies could be based on the following topics:

1. An extensive study could be done on each of the elements of the equipment replacement policy separately. The practices could be analyzed analytically to determine the optimum practice for the conditions in the country.
2. Analytical models could be developed for determining the feasibility of the different alternative equipment at the time of acquisition and replacement. Computers could be used to develop software models that will be more effective and it will save time and resources to implement them.

3. **Analytical models could be developed for determining the economic life and the replacement time of the equipment. Computers could be used to develop software models that will be more effective and it will save time and resources to implement them.**
4. **Expert systems could be developed that help the contractors in making decision covering the working life of the equipment.**

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**Appendix A**  
**RESEARCH QUESTIONNAIRE**

## **RESEARCH QUESTIONNAIRE**

### ***1.0 General Information:***

1.1 Please indicate the type of construction your firm is doing:

- Residential Building
- Commercial Building
- Industrial
- Heavy
- Other (please specify)

1.2 How long has your company been in the construction business?  
(       ) Years

1.3 What percentage of the equipment you use do you own?

- Ownership (       ) %
- Lease (       ) %
- Rental (       ) %

1.4 What is the approximate annual work volume of your company?  
(       ) Saudi Riyals

1.5 What are the types of equipment the company mostly uses? (Please list)

Type	Brand	Power	Capacity	Number of Equipment
------	-------	-------	----------	---------------------

1.6 What is the current value of your equipment fleet?  
(       ) Saudi Riyals

### ***2.0 Equipment Management Policy:***

2.1 Do you have a written construction equipment management policy?

- Yes
- No

2.2 What are the contents of the equipment policy?(Please check all that apply)

- Selection
- Purchasing
- Equipment economic evaluation
- Equipment usage



- Equipment maintenance
  - Maintenance of equipment cost and production records
  - Allocation of equipment operators
  - Equipment security
  - Equipment standardization
  - Equipment replacement
  - Equipment disposal
  - Others (Please specify)
- 2.3 When was the equipment policy developed?  
( ) Year
- 2.4 How frequently do you update the equipment policy?
- Monthly
  - Yearly
  - Job-wise
  - Other periods (Please specify)

### **3.0 Equipment Replacement Policy:**

#### **3.1 General:**

- 3.1.1 Do you have a written construction equipment replacement policy?
- Yes
  - No
- 3.1.2 Do you have a stand-alone equipment replacement policy manual or is it just a section of the equipment management policy manual?
- Stand-alone policy
  - Section (part) of the equipment management policy manual
- 3.1.3 What are the contents of the equipment replacement policy? (Please check all that apply)
- Stipulated procedure for conducting the replacement analysis
  - Required equipment replacement forms and procedures to complete them
  - Organizations to be involved in the evaluation process
  - Evaluation team members qualification requirements
- 3.1.4 How often do you update the equipment replacement policy?
- Monthly
  - Yearly
  - With the Equipment Management Policy
  - Other periods (Please specify)

### **3.2 Replacement Analysis:**

- 3.2.1 How does your company decide when to replace equipment?
- Economic study
  - Replacement when equipment becomes inefficient
  - Usually replace before a new job
  - Usually replace before a major overhaul
  - Replace when equipment become obsolete
  - Replace if the financial picture is good
  - Others (Please specify)
- 3.2.2 When does your firm tend to replace equipment more frequently?
- When jobs are highly competitive
  - When competition is relatively low
  - Policy does not change
  - Others (Please specify)
- 3.2.3 What minimum size of equipment investment do you consider as a major equipment investment worthy of quantitative evaluation? Please indicate volume of investment (purchase price of equipment):  
(       ) Saudi Riyals
- 3.2.4 Please list in order of importance the qualitative factors that influence your investment decisions
- Employee morale
  - Employee safety
  - Environmental responsibility
  - Image (in industry, among customers)
  - Management goals
  - Others (Please specify)
- 3.2.5 Which organizations/departments are involved in the equipment replacement analysis?
- Equipment department
  - All related company organizations
  - External consultant
  - Others (Please specify)
- 3.2.6 From which organizational levels do equipment replacement proposals originate?
- Replacement analysis team
  - Equipment department
  - Financial department
  - Others (Please specify)

- 3.2.7 Who in your organization generally makes the final decision regarding equipment acquisition and disposition?
- President (CEO)
  - Board of Directors
  - Project Manager
  - Equipment Manager
  - Others (Please specify)
- 3.2.8 Which of the following methods do you use to determine the optimum replacement time for a piece of equipment?
- Generation of a report cost curve and replacement when a determined target value is achieved
  - Replacement when cost for necessary repairs seems to be too high
  - Determination of the economic life of equipment and replacement at the end of this period
  - Others (Please specify)
- 3.2.9 Do you use software program(s) to do the equipment replacement analysis?
- Yes
  - No

**3.3 Financial Evaluation of Equipment Replacement proposals:**

- 3.3.1 Is long range planning formally prepared in your company?
- Yes
  - No
- 3.3.2 Are standard forms generally used for capital budgeting and appropriation requests?
- Yes
  - No
- 3.3.3 What kind of financing do you use to acquire equipment?
- Outright purchase (By cash from retained earnings)
  - Short-term bank loans (Less than one year)
  - Long-term bank loans (Greater than one year)
  - Service leases (Financial)
  - Trade credits
  - Others (Please specify)
- 3.3.4 How do you determine a minimum rate of return for your accept-reject decision, applying internal rate of return?
- Cost of a specific source of funds
  - Weighted cost of sources of funds

- Management determined target rate of return
- Firm's historical rate of return
- Others (Please specify)

3.3.5 If you compare cash flows, how do you determine the receipts of the different proposals?

- Directly allocating revenues to the equipment investment
- Using rental rates from local equipment dealers
- Using rental rates as suggested by governmental agencies
- Calculating internal rates based on in-house data
- Others (Please specify)

3.3.6 What do you compare in the quantitative evaluation of equipment investment proposals?

- Disbursements of alternatives
- Net cash flows ( = receipts - disbursements ) of alternatives

3.3.7 Circle the financial methods that are commonly used to evaluate the equipment replacement proposals.

1. Payback period (PBP)
2. Net present value (NPV)
3. Internal rate of return (IRR)
4. Comparative annual cost method (CAC)
5. MAPI method
6. Economic life (EL)
7. Profitability index (PI)
8. Others (specify)

In the table below please specify the reasons for using the above methods using the following scale:

- 1 = Strongly Agree
- 2 = Agree
- 3 = Neutral
- 4 = Disagree
- 5 = Strongly Disagree
- 6 = Method is not used

**"Place your answers in the appropriate box in the table"**

REASONS	Mthd 1 "PBP"	Mthd 2 "NPV"	Mthd 3 "IRR"	Mthd 4 "CAC"	Mthd 5 "MAPI"	Mthd 6 "EL"	Mthd 7 "PI"	Mthd 8 Others
1. Simplicity								
2. Input data available								
3. Require excessive knowledge of accounting								
4. Guideline range is available								
5. Measure the future risk period								
6. Measure the rate of return								
7. Measure the worth of the alntv.								
8. Consider time value of money								
9. Consider expected salvage value								
10. Consider obsolescence and Deterioration								
11. Determine the expected economic life								

3.3.8 What depreciation accounting method do you use for construction equipment?

- Straight line method
- Double-declining balance method
- Sum-of-years-digits method
- Percent of life
- Others (please specify)

3.3.9 Which of the following factors do you consider in your replacement analysis?

- Inflation
- Escalation
- Downtime costs
- Obsolescence
- Depreciation
- Taxes
- Time value of money
- Others (Please specify)

3.3.10 Do you use actual maintenance and operating cost records for individual units (or groups) in making replacement decisions?

- Yes
- No
- Sometimes

3.3.11 Does obtainable salvage value (net resale price) influence decisions?

- Yes
- No
- Sometimes

3.3.12 What do you think are important items in determining the economic life of equipment? Please indicate your choices:

- Depreciation and replacement costs
- Investment costs
- Maintenance and repair costs
- Downtime costs
- Obsolescence costs
- Profit accrued from use
- Tax advantages
- Others (please specify)

3.3.13 When do you consider your equipment to be obsolete?

- Manufacturer is out of business or does not support its spare parts
- New models that are more productive and require less operating cost are available
- Equipment's economic life is exceeded, and it has become under productive

3.3.14 At what annual rate do you estimate obsolescence occurs in construction equipment?

(        ) %

#### **4.0     Equipment Record Keeping:**

4.1     Please check the types of cost records you maintain for individual equipment:

- Operating hours
- Repair costs
- Overhaul costs
- Operating expenses (fuel, lubricants, filters, etc.)
- Others (Please specify)

4.2     How often is a production-time-cost report made?

- Daily
- Weekly
- Monthly
- Job-wise
- Others (Please specify)

4.3     At what level is the data gathered?

- Job Superintendent
- Foreman (Craft/General job)
- Operator
- Mechanic
- Others (Please specify)

- 4.4 Do you use computers for equipment record keeping?
- Yes
  - No

**5.0 Miscellaneous**

- 5.1 How do you dispose of your equipment?
- Trade to dealer
  - Auction sale
  - Sell to others (Third party)
  - Other (Please specify)
- 5.2 What is your company policy regarding new, improved models of equipment that appear to be superior to yours? Please indicate your preferences.
- Buy immediately
  - Buy to replace inefficient equipment
  - Test by renting before buying
  - Wait till bugs are known
  - Others (Please specify)
- 5.3 Please indicate the level of maintenance that you normally do in-house?
- Lubrication and filter change only
  - All repair jobs
  - Overhauls
  - None

**Appendix B**  
**LIST OF CONTRACTORS**



1. Hammad B S Establishment (Saudi Building Co. Aba-Husain & Bros.)
2. Abdullah A Al-Dossery Establishment
3. Hashem Bin Al-Said Al-Hashem Office
4. Al-Fouzan Trade & Contracting Comapny
5. Foud Abdulla Foud Corporation Establishment
6. Mohammad S Al-Joaib & Partener Company
7. Al-Tammimi Company
8. Saleh & Abdulaziz Aba-Husain Company Incorporation
9. Al-Wabel Establishment
10. Arabian Gulf Construction Company Limited
11. Ahmed H Al-Muhana Trading & Contracting Establishment
12. Al-Haider Company for Trading & Contracting
13. Al-Nafjan Trading & Contracting Establishment
14. Mohammad Salem Al-Swaidi Contracting Establishment
15. Abdullah Al-Hamood Al-Shuwayer Establishment
16. Saleh Naser Wabran Al-Yamee Establishment
17. Al-Kashgari Bros Company
18. Abdullah A M Al-Khodari Establishment
19. Hazal A Al-Otaibi Establishment
20. Nasser Bin Hazza Al-Sebaiey & Brothers Company Limited
21. Najran Trading & Contracting Company
22. Qasim Bin Haroon Al-Haroon Establishment
23. Abdulrahman Ali Al-Turki Trading & Contracting Establishment
24. Abdullah M Al-Yuoseif Trading & Contracting Establishment
25. Jafal Obaid Al-Shammary & Brothers Company
26. Al-Amar Establishment for Trading & Structure
27. Aayedh Nassir Al-Qahtany Contratcing Establishment
28. Salem A Al-Duhaim Establishment
29. Contratcing & Commercial Development Establishment
30. Mohammad Al-Mojil Establishment
31. Khalid Bin Hamad Al-Dossary Establishment
32. Hadi Haider Al-Yami & Bros Company
33. Fahad A Al-Khaldi & Brothers Company
34. Yousuf M Al-Dossari Contracting & Trading Establishment
35. Abdulla Said & Partners Company
36. Al-Yamama Company for Trade & Contracting Work
37. Abdulaziz Al-Ejaimi & A Al-Jalhami Company
38. Al-Hammad Trading & Contracting Company
39. Ebraheem A Al-Sohaibany & Partners Company
40. Abdullah Rashid Dossary & Partner Company
41. Al-Kefah Trading & Contracting Establishment
42. Emad Trading & Contracting Establishment
43. Saudi Electrical & Mechanical Construction Company Limited
44. Mohammad S AL Iriq for Trading & Contracting
45. Al-Najim Saudi International Company Limited

46. Mohammad Al-Othman Establishment for Trading and Contracting
47. National Bids Company
48. Al-Muhaidab Trading & Contracting Company
49. Faleh S Al-Hajery Establishment
50. Al-Thobaiti & Brothers Company
51. Al-Najim Contracting Trading & Services Establishment
52. Ali Al-Yami & son for Trading & Construction Company
53. Abdulaziz Al-Traiki & Company for Trading & Construction
54. Mohammad Al-Ojaimy Trading & Construction Establishment
55. Abdulmohsen A Al-Tamimi Establishment
56. Salem S Al-Dossary Establishment
57. Al-Turky Establishment for Trading & Contracting
58. Al-Abdulrahman Trading & Contracting Establishment
59. Abdullah M Arajani Brothers Company
60. Al-Dubaib & Al-Sulaim Company (DESCO)
61. Al-Aswad Establishment for Trading and Contracting
62. Saleh Al-Ghamdi Commercial & Contracting Establishment
63. Interedec-Aswad Contracting & Engineering Company Limited
64. Contracting, Importing, & General Services Enterprise Company
65. Ali Mohammad Al-Ajina Establishment
66. Batal R Al-Ghairy Al-Dossary & Partners Company
67. Mohammad S Al-Subaiy Contracting Establishment
68. Gulf Contractors Company Limited
69. Redec Dailim Saudi Arabia Company
70. Modern Arab Construction Company Limited
71. Ajaab Arabian Limited Company
72. Saudi Electric & Development Company
73. Boskalis Westminster Al-Rushaid Comapany Limited
74. Middel East Engineering & Development Company Limited